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PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852.)

VOL. XXXIII. No. 6.

AUGUST, 1907

Edited by the Secretary, under the direction of the Committee on Publications.

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NEW YORK 1907.

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American Society of Civil Engineers.

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ON STATUS OF METRIC SYSTEM:—Stacy B. Opdyke, Jr., John Waterhouse, D. A. Molitor.

ON ENGINEERING EDUCATION:—Desmond FitzGerald, Benjamin M. Harrod, Onward Bates, D. W. Mead, Charles Hansel.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER....................5913 Columbus.
CABLE ADDRESS......................"Ceas, New York."

Vol. XXXIII. AUGUST, 1907. No. 6.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

May 15th, 1907.—The meeting was called to order at 8.45 P. M.; Director G. W. Tillson in the chair; Chas. Warren Hunt, Secretary; and present, also, 156 members and 27 guests.

A paper by William H. Burr, M. Am. Soc. C. E., entitled "The Reinforced Concrete Bridge Across the Hudson River at Sandy Hill, New York," was presented by the author, and discussed orally by Messrs. E. W. Stern, L. L. Tribus, A. Atkinson, and D. W. Krellwitz. The Secretary presented a written communication on the subject from H. H. Quimby, M. Am. Soc. C. E.

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The Secretary announced the following deaths:

CHARLES HAYNES HASWELL, elected Member January 29th, 1868; Honorary Member May 12th, 1905; died May 12th, 1907.

NATHANIEL HENRY HUTTON, elected Member June 3d, 1896; died May 8th, 1907.

HIEL HAMILTON FILLEY, elected Member January 3d, 1883; died May 6th, 1907.

Adjourned.

June 5th, 1907.—The meeting was called to order at 8.40 P. M.; Director A. L. Bowman in the chair; Chas. Warren Hunt, Secretary; and present, also, 108 members and 18 guests.

The minutes of the meetings of April 17th and May 1st, 1907, were approved as printed in the *Proceedings* for May, 1907.

A paper by Arthur L. Adams, M. Am. Soc. C. E., entitled "A Solution of the Problem of Determining the Economic Size of Pipe for High-Pressure Water-Power Installations," was presented by the Secretary, who stated that he had received communications on the subject from Messrs. W. L. Butcher and W. E. Buck, but would not read them on account of their mathematical nature. The paper was discussed orally by Messrs. E. Kuichling and E. P. Goodrich.

The Secretary presented the following communication relative to the appointment of a special committee on underground piping in city streets.

"DETROIT, November 22d, 1906.

"TO THE AMERICAN SOCIETY OF CIVIL ENGINEERS,

"GENTLEMEN:

"We, the undersigned members of your Society, respectfully request that a special committee be appointed to consider the subject of underground piping in city streets, with a view to recommending standard street sections, following which, municipal engineers, elected for short terms only, could lay out new work, not only to meet present needs, but also to give convenient and economical access to sewer, water, and other pipes, as the city grows.

"We believe that the present custom of constantly tearing up expensive pavements to get at piping laid under them is on the increase rather than decrease, and might be largely avoided by the work of a special committee whose duty would be to recommend among other things:

"a. Arrangement of piping in new streets.

"b. Re-arrangement of piping in older streets when about to be paved.

"c. Subways or re-arrangement of piping in business streets to meet modern needs of sewer, water, gas, telephone, heat, pneumatic tube, areas, etc., etc.

"Such a report would, by furnishing a standard, enable engineers to get the approval of Councils, and Boards, and Legislatures, to more up-to-date plans than would now be considered.

"This subject we consider one peculiarly adapted for the consideration of the Society, because municipal engineers have been too subject to political caprice to have been able to work out the problem of economically arranging the modern piping and modern pavements of city streets.

"Respectfully submitted,

"RUTGER B. GREEN
CLARENCE W. HUBBELL
BENJAMIN DOUGLAS
ALEX DOW
R. H. McCORMICK
GEO. H. FENKELL
E. E. HASKELL
C. L. CRANDALL
E. J. McCAUSTLAND
I. P. CHURCH
CLYDE POTTS
R. F. PROCTOR
R. B. WILLIAMS, JR.
HENRY C. ALLEN
W. B. COGSWELL
GARDNER S. WILLIAMS."

It was moved that the matter be referred to the Board of Direction (Art. VI, Sec. 12, of the Constitution).

The motion, being duly seconded, was adopted by a vote of forty-three Corporate Members.

Ballots for membership were canvassed, and the following candidates elected:

AS MEMBERS.

CHARLES PHILLIP BOWER, Philadelphia, Pa.
MARVIN CHASE, Wenatchee, Wash.
WILLIAM HENRY CODE, Hollywood, Cal.
JAMES DEARING FAUNTLEROY, Lynch Station, Va.
JOHN LYELL HARPER, Niagara Falls, N. Y.
HANS LUDWIG HELDT, Sombrerete, Zacatecas, Mexico.
HENRY JERVEY, Mobile, Ala.
MAURICE EDWIN KERNOT, Melbourne, Victoria, Australia.
RICHARD BIRD KETCHUM, Helper, Utah.
ELWOOD NORMAN LAYFIELD, Chicago, Ill.
MARCUS WINFIELD LEWIS, Superior, Wis.
MANUEL MARROQUIN Y RIVERA, City of Mexico, Mexico.
GUILLERMO BELTRAN Y PUGA, City of Mexico, Mexico.
HIRAM JOSEPH SLIFER, New York City.
WILLIAM GAVIN TAYLOR, Waterbury, Conn.
GEORGE WESTON, Chicago, Ill.

As Associate Members.

William Townsend Anderson, New York City.
Edward Franklin Atwood, Boston, Mass.
Daniel William Bliem, East Berlin, Conn.
Norman Freed Brown, Pittsburg, Pa.
Edward Beauford Cauthorn, Columbia, Mo.
George James Schilling Collins, Omaha, Nebr.
Henry Stratford Devlin, New York City.
William Henry Dorsey, Baltimore, Md.
Arthur Cassidy Everham, Detroit, Mich.
Joseph Firth, Philadelphia, Pa.
Clinton Hinckley Fisk, New Orleans, La.
Murray Forbes, Greensburg, Pa.
Frank George Fowler, Mount Kisco, N. Y.
Walter Nettleton Frickstad, Berkeley, Cal.
Eric Hjalmar Frisell, City of Mexico, Mexico.
Alfred Cookman Gregory, Trenton, N. J.
Albert Valdemar Gude, Jr., Atlanta, Ga.
Walter Scott Hanna, Harrisburg, Pa.
Guy Walter Harris, Canyon, Tex.
Carl Hiram Holley, Visalia, Cal.
Wilhelm Jens Christian Howalt, Ridgway, Pa.
Harry Ludwig Maier, Wilmington, Del.
Charles Michael Morssen, New York City.
Cornelius Joseph O'Connor, New York City.
Marshall Barker Palmer, Rome, N. Y.
Frederick Atwood Pease, Cleveland, Ohio.
Alvin Cyrus Pflueger, New York City.
Charles Arthur Poole, Albany, N. Y.
Alfred Clare Reed, Mayari, Cuba.
William Belden Reed, Jr., White Plains, N. Y.
Charles Gordon Reel, Kingston, N. Y.
Phillip Jacob Reich, Toledo, Ohio.
John Francis Richardson, Grants Pass, Ore.
Malcolm Asher Rue, New York City.
Joseph Carl Schaeffler, Boston, Mass.
John Martin Schreiber, Newark, N. J.
Frederick Celestine Schubert, Celilo, Ore.
Layton Fontaine Smith, Baltimore, Md.
William Thomas Clare Spiker, Roanoke Rapids, N. C.
Grandison Gridley Underhill, Albany, N. Y.
Henry William Vehrenkamp, Cincinnati, Ohio.
Johannes Cornelis Vliegenthart, Tientsin, China.
Michael Wassner, Corry, Pa.
William Hammond Waugh, Greenville, Pa.

HOWARD SHAY WILLIAMS, Buffalo, N. Y.
CHRISTOPHER STANTON WOLCOTT, Brooklyn, N. Y.
GEORGE WOOD, New York City.
JOHN STEPHEN WORLEY, Toledo, Ohio.

AS ASSOCIATES.

CAMERON C. SMITH, Pittsburg, Pa.
EDWARD PERCIVAL THOMPSON, Manila, Philippine Islands.

The Secretary announced:

The transfer of the following candidates by the Board of Direction on June 4th, 1907:

FROM ASSOCIATE MEMBER TO MEMBER.

BRYAN CHEVES COLLIER, New York City.
ROBERT LADD GIFFORD, Chicago, Ill.
ARTHUR STANLEY HOBBY, Havana, Cuba.
FRANK FORREST SINKS, Chicago, Ill.

The election of the following candidates:

AS JUNIORS.

On April 2d, 1907:

JAMES LAFAYETTE PARKER, New York City.

On April 30th, 1907:

MICHAEL SMITH HARVEY, Ruby, Miss.
WILLIAM VINCENT MCMENIMEN, New York City.
FORREST LEIGH SMITH, Perth Amboy, N. J.

On June 4th, 1907:

FREDERIC BURROUGHS, Aspinwall, Pa.
JAMES KIP FINCH, Easton, Pa.
HARRY MINOTT GOODMAN, Berkeley, Cal.
FREDERICK NATHANIEL HATCH, Ely, Nev.
RALPH DANIEL HAYES, Goshen, N. Y.
FREDERIC LEAROYD HUMPHREY, Selden Station, N. Mex.
FRITZ MILLER, Nampa, Idaho.
HENRY LANARK MILLER, Santa Fé, Argentine Republic.

The Secretary announced the following deaths:

Sir BENJAMIN BAKER, elected Honorary Member May 5th, 1897; died May 19th, 1907.

CALVIN EASTON BRODHEAD, elected Member February 21st, 1872; died April 29th, 1907.

Daniel Farrand Henry, elected Member July 7th, 1875; died May 13th, 1907.

Merritt Harrison Rogers, elected Member January 2d, 1890; died May 3d, 1907.

Adjourned.

ELECTIONS TO MEMBERSHIP.

The following candidates were elected on ballot canvassed July 10th, 1907:

As Members.

John Allen Beeler, Denver, Colo.
Waldo Clayton Briggs, New York City.
Walter Wilson Crosby, Baltimore, Md.
Herbert Chapin Daggett, Boston, Mass.
John Bagley Dimmick, Pittsburg, Pa.
Edwin George Evans, Hampton, N. B., Canada.
John Lincoln Hall, New York City.
John Wilson Hamilton, New York City.
Robert Francis Hayward, Mexico, D. F., Mexico.
Samuel Hamilton Hedges, Seattle, Wash.
Ernest Rowland Hill, New York City.
Ernest George Hopson, Portland, Ore.
Arthur Lewis Jones, Ogden, Utah.
Samuel Lippincott Griswold Knox, Milwaukee, Wis.
Balie Peyton Legaré, San Francisco, Cal.
Henry Martyn MacKay, Montreal, Que., Canada.
Peter Mogenson, Spokane, Wash.
John Edward Schwitzer, Winnipeg, Man., Canada.
John Maxwell Sherrerd, Easton, Pa.
Thomas Cullen Bryant Snell, Lynchburg, Va.
Warren Powell Wood, Lewiston, Idaho.

As Associate Members.

William Greene Atwood, Cleveland, Ohio.
John Vanderveer Beekman, Jr., Boston, Mass.
Newton Davis Benson, Providence, R. I.
John Henry Bowditch, New Brighton, N. Y.
Orrin Lawrence Brodie, New York City.
Clarence Edson Carpenter, Yonkers, N. Y.
William Dexter Clarke, Milford, Cal.
Loren Bradley Curtis, Denver, Colo.
Ernest Franklin Deacon, Altapass, N. C.
Brent Skinner Drane, Carlsbad, N. Mex.
Robert Willson Fenn, Panama, Panama.

Paul Evans Green, Chicago, Ill.
Gustaf Edward Gustafson, Chicago, Ill.
John Lawrence Hyde, Westfield, Mass.
Ernest Lee Jahncke, New Orleans, La.
Vernet Albert Kauffman, Nueva Casas Grandes, Chihuahua, Mexico.
Forest Henry Lancashire, Monterey, Mexico.
William Caswell Smith Lemen, Brunswick, Ga.
Drew Jones Linard, McCall Ferry, Pa.
Paul McGeehan, Boone, Iowa.
Royal John Mansfield, Manila, Philippine Islands.
Charles Maynard Mapes, New York City.
Thomas Herbert Means, Fallon, Nev.
George Emil John Pistor, East Orange, N. J.
Walter Frederick Reichardt, Little Rock, Ark.
Franklin Henry Robbins, Pittsburg, Pa.
Herbert Fulwiler Robinson, Santa Fé, N. Mex.
Norman Salisbury Sprague, Pittsburg, Pa.
Charles Underhill Stepath, New York City.
Stuart Augustus Stephenson, Jr., Caguas, Porto Rico.
Charles August Thanheiser, Houston, Tex.
Charles Clarence Ward, Corbett, Wyo.
Joseph Weidel, Trinidad, Colo.
Thad Loren Wilson, New York City.

As Associates.

Charles Henry Eglee, Boston, Mass.
James Joseph Ferris, Jersey City, N. J.
Hermann Von Schrenk, St. Louis, Mo.

THIRTY-NINTH ANNUAL CONVENTION
HELD IN MEXICO CITY, MEXICO, JULY 8th-10th, 1907.

PRELIMINARY MEETING.

Monday, July 8th, 1907, 8.30 P. M.—A preliminary meeting was held at the "Mineria," in the City of Mexico, Sr. Leandro Fernandez presiding. Sr. J. Ramón Ibarrola, representing the Mexican Society of Engineers and Architects, delivered an address of welcome to the Society.

Onward Bates, Vice-President, Am. Soc. C. E., responded in behalf of the Society.

Hon. Leandro Fernandez, Minister of Public Works of Mexico, and President of the Mexican Society of Engineers and Architects, then, in the name of the association, declared the Thirty-ninth Convention of the American Society of Civil Engineers formally inaugurated.

BUSINESS MEETING.

First Session of the Convention, Tuesday, July 9th, 1907. —The meeting was called to order at 8.30 P. M.; Vice-President Onward Bates in the chair; Charles Warren Hunt, Secretary; and present, also, about 60 members and a number of guests.

The Secretary presented a report giving the result of the suggestions of members as to the time and place for holding the Annual Convention of 1908.*

The subject was discussed, and on motion, duly seconded, was referred to the Board of Direction with power.

The Secretary presented a report relating to the vacancy on the Nominating Committee due to the death of the late Charles Davis, M. Am. Soc. C. E., stating that he had been instructed by the Board of Direction to call the attention of the Business Meeting of the Annual Convention to this fact.

On motion, duly seconded, it was resolved that no action be taken.

A report from the Special Committee on Rail Sections was presented by the Secretary.†

The report was not discussed, and on motion, duly seconded, was ordered printed in *Proceedings*, the whole matter being left open for discussion by the membership of the Society, and the report made an order of business for the next Annual Meeting.

Adjourned.

* See page 279.
† See page 290.

Second Session, Wednesday, July 10th, 1907.—The meeting was called to order at 10 A. M.; Vice-President Onward Bates in the chair; Charles Warren Hunt, Secretary; and present, also, about 125 members and guests.

The Secretary presented the Annual Address of President George H. Benzenberg, entitled "The Engineer as a Professional Man."*

The first topic for discussion was then taken up, the topic being the following:

"Is it a better policy to purchase and control water-sheds, thereby preventing the pollution of impounding reservoir supplies, or to suffer a certain amount of pollution of such supplies, relying upon filtration to correct the effects thereof?"

The opening discussion on this subject, by George W. Fuller, M. Am. Soc. C. E., was then read, as was also a written communication from George A. Soper, M. Am. Soc. C. E. Discussions on this subject, by Messrs. F. Herbert Snow, D. D. Clarke, Pablo Solis and Octavio Guzmân, were presented by title, and the subject was further discussed orally by Messrs. M. Marroquin, M. R. Sherrerd, Gardner S. Williams, J. T. Noble Anderson, William B. Fuller, J. Waldo Smith, F. W. Blackford, S. Bent Russell, William J. Baldwin, and Charles B. Ball.

The second topic for discussion was then taken up, the topic being the following:

"(*a*) What is the best system of construction for foundations of heavy structures on ground such as that of the City of Mexico, which is an alluvial deposit about 300 ft. in depth, and similar in character to that at New Orleans?"

"(*b*) Will iron or steel used in foundations, independently or in combination with other materials, last indefinitely when in direct or indirect contact with water?"

"(*c*) Will the strength and durability of concrete in foundations be affected if before setting there is : (1) an excess of water; (2) lack of compression; (3) too rapid desiccation?"

The Secretary read the opening discussion by John F. O'Rourke, M. Am. Soc. C. E. Mr. Marroquin then presented in English an abstract of a paper on this subject prepared by Mr. Gilberto Monteil, and also spoke upon the subject personally, and the topic was further discussed by Messrs. Lansing H. Beach, Miguel Rebolledo, Henry W. Hodge, G. E. P. Smith, and F. G. Jonah, and the Secretary presented by title written discussions by Messrs. J. C. Meem, M. Morssen, J. A. L. Waddell, Pablo Solis and Octavio Guzmân.

Adjourned.

* *Transactions*, Am. Soc. C. E., Vol. LVIII, p. 515.

Third Session, Wednesday, July 10th, 1907.—The meeting was called to order at 3 P. M.; Vice-President Onward Bates in the chair; Charles Warren Hunt, Secretary; and present, also, about 100 members and guests.

The following topic was discussed:

"Will the paving materials of the present be used in the construction of the pavements of the future?"

The Secretary presented the opening discussion, prepared by George W. Tillson, M. Am. Soc. C. E., and the subject was discussed by Messrs. Horace Andrews, Lansing H. Beach, N. P. Lewis, E. M. T. Ryder, and G. S. Williams, and the Secretary presented written communications on the subject from Messrs. J. H. Haylow, P. W. Henry, Clifford Richardson, and W. H. Lawton.

The fourth topic was then taken up for discussion, the topic being as follows:

"(*a*) What are the factors which determine the maximum economical grade for electric railways?"

"(*b*) In establishing direct lines with heavy grades, under what conditions will it be found practicable to use electric locomotives and gas-engine generating stations, rather than traction by steam locomotives?"

The Secretary presented the opening discussion on this subject, prepared by George Gibbs, M. Am. Soc. C. E. The subject was discussed orally by Messrs. R. H. Hayward, W. W. Follett, J. T. Noble Anderson, and T. A. Corry.

Adjourned.

Fourth Session, Wednesday, July 10th, 1907.—The meeting was called to order at 8 P. M.; Vice-President Onward Bates in the chair; Charles Warren Hunt, Secretary; and present, also, 75 members and guests.

The following topic was taken up for discussion:

"(*a*) What is the best apparatus and most economical system for cleaning producer or furnace gas, to be used in gas engines?"

"(*b*) To what extent is ordinary producer gas, made from bituminous coal, used in gas engines, and what practical results have been obtained by any methods for removing tar or soot?"

The Secretary presented the opening discussion, prepared by James Christie, M. Am. Soc. C. E., and by title written communications on the subject from Messrs. Robert H. Fernald and Tomilion Geelen, and the subject was discussed by Messrs. Buchanan and J. Waldo Smith.

On motion, duly seconded, the chairman was authorized to appoint a committee to draft suitable resolutions expressing the thanks of the Society and its appreciation of the hospitality extended to the party in Mexico.

On motion, duly seconded, it was moved that the courtesies of the House of the American Society of Civil Engineers be extended to the Mexican Association of Engineers and Architects, and to the Mexican Association of Military Engineers, both of the above motions being carried unanimously.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

June 4th, 1907.—Past-President Stearns in the chair; Chas. Warren Hunt, Secretary; and present also Messrs. Bowman, Gibbs, Hazen, Hodgdon, Noble, Sherrerd and Tillson.

A payment of $10 000 on the principal of the mortgage on the Society House was authorized to be paid July 1st, 1907.

The following Special Committee was appointed to report on the status of Engineering Education in this country, and to recommend measures calculated to place it on the highest plane of efficiency:

DESMOND FITZGERALD, *Chairman;*
BENJAMIN M. HARROD, D. W. MEAD,
ONWARD BATES, CHARLES HANSEL.

Applications were considered, and other routine business transacted.

Tuesday, July 9th, 1907.—The Board met, in accordance with the Constitution, during the Thirty-ninth Annual Convention, Onward Bates, Vice-President, in the chair; Charles Warren Hunt, Secretary; and present, also, Messrs. Bowman, Sherrerd and Smith.

No quorum being present, the Board then adjourned.

REPORT IN FULL OF THE PRELIMINARY SESSION OF THE THIRTY-NINTH ANNUAL CONVENTION, AND OF THE BUSINESS MEETING, HELD IN THE "MINERIA," IN THE CITY OF MEXICO.

PRELIMINARY MEETING.

Monday, July 8th, 1907, 8.30 P. M.

The meeting was called to order at 8.30 P. M. in one of the halls of the "Mineria," in the City of Mexico, by Hon. Leandro Fernandez, Minister of Public Works, and President of the Mexican Society of Engineers and Architects, when the following programme was carried out.*

Address of Welcome by Sr. J. Ramón Ibarrola, C. E., as Representative of the Mexican Society of Engineers and Architects.

Sr. J. Ramón Ibarrola.—Gentlemen of the American Society of Civil Engineers, and Ladies: Acting on a proposal of our honored President, who in such a worthy manner fills the prominent position of Secretary of Communications and Public Works in the Cabinet of the President of the Republic, who has bestowed upon me the undeserved distinction of tendering the American Society of Civil Engineers a hearty welcome on the occasion of their visit to this our capital city, where their thirty-ninth convention is to be held; I feel under great obligations for the honor that befalls me. I recognize that I owe it not to any merit on my part, but simply to the fact of my being one of the oldest members of our profession in the Republic, one of the founders of our association, and one who, having resided in the United States at many different times, has become familiar with the wonderful works of that most wonderful country, where he has been honored by the friendship of such men as Alexander Holley, Eckley B. Coxe, Professor Morton, John Fritz, and so many more who enjoy a world-wide reputation, and to whose kindness he owes the most flattering distinctions. At the same time, I must acknowledge my utter inability to express in a worthy manner the feelings of my brother engineers on this solemn occasion, when we see among us in this time-honored historical hall so many brilliant representatives of the noble profession of engineering in its multifarious branches. It is certainly a great treat to have you American engineers sitting side by side with us at this gathering, of which nobody dreamed in not a very distant past, and that has become possible, easy, and pleasant, thanks to the steel ribbons that bind together your northernmost

Address of Welcome.

*Several musical selections, by an orchestra furnished through the courtesy of the Hon. Leandro Fernandez, were given during the session.

Address of Welcome (continued). cities, nay, the cities of Canada, with our principal cities and the banks of the Rio Bravo, along our Central Plateau, down to the Gulf of Mexico, the Pacific Ocean and our southern frontier. Our intercourse during the days you are to spend here will be very pleasant and useful to you, our distinguished guests, and to us, your cordial hosts, since you bring us the ripe fruits of a science gathered in your technical schools, and in your universities, and in the experience acquired in so many works that most deservedly astonish the world by the greatness of their conception and the wonderful methods and appliances used in their execution.

In dealing with the topics selected for general discussion at this convention, we expect to offer you an excursion to the new waterworks, designed and now under construction for the supply of the City of Mexico, and, as the engineer who is the author of these works, and is their actual director, will be with us, he will lay before you the thorough and exhaustive surveys and studies that preceded and determined the adoption of the plans, the execution of which has been entrusted to his recognized ability. You will, in return, give us your sincere opinion on the same, and tell us something about the colossal work undertaken in your country for the water supply of Greater New York. In that way, while you will be enabled to judge by your own inspection of what our engineers can do and the way in which they do it, we, on our part, will avail ourselves of your advice and your experience, turning them to great profit.

It will be a great honor for me, as Director of the Hydrographic Commission of the Republic, to invite you to an excursion to the Drainage Works of the Valley of Mexico, and to give you on the very ground on which they are located a cursory description of the topography and the hydrography of that most interesting basin. Your attention will thus be drawn to the wonderful work of the Aztec Emperors, long before the Spanish conquest, to those executed by the Spaniards in the Colonial period of our history, and finally to the grand work undertaken and executed by the firm, wise, and far-sighted administration of our actual President. a work that constitutes one of his greatest and purest glories, and the completion of which we all hope he will live long enough to witness, and which will solve in a definite way the complex problems of drainage of the Valley of Mexico and the proper disposal of the waters that flow into it from the lofty mountains by which it is surrounded and entirely enclosed. This afforded the possibilities of undertaking the proper sanitation of the City of Mexico, carried out according to the plans of one of our most brilliant engineers, and whom you count among the members of your society.

The operations required for the drainage of the valley and those

executed for the construction of the sewers in the city have produced deep alterations in the statical conditions of its soil, and these have made themselves felt mostly by the sinking of old buildings, and of some more recently built, and a variation of the levels in several points of the valley. This fact has led to very interesting investigations about the proper kind of foundations to be adopted in our city, and a good many exhaustive researches and practical experiences have been made by several of our engineers, mostly by the distinguished Under-Secretary of Communications and Public Works, whose modesty has deprived the scientific world of the valuable results of his long and scrupulous labors.

As the question of foundations will be one of the topics dealt with in our sessions, I expect our engineers will lay before our American friends the facts relating to such interesting problems that the discussions about them cannot fail to be exceedingly important, since there are so many delicate points underlying the same, on account of the drainage of the City of Mexico and the surrounding country, owing to the sewers established in the former and to the flow of the water from the soil toward the main outlet of the valley.

Another question submitted to your convention has acquired a great importance; it is that relating to pavements. I have no doubt that the Direction of Public Works, having under its control works of a municipal character, will give us the most interesting data on this subject.

In dealing with these and the other questions that may arise in the course of our discussion, your advice, brother engineers from the North, will be for us a most valuable contribution. You come from a country where every day a new scheme surprises the world by the boldness and novelty of its features. Whatever you dream at night you turn into a reality the next morning. You have raised to the region of the clouds those wonderful buildings, some of them real architectural marvels, cut in marble and granite, and masterpieces of engineering skill and design, and the construction of their steel frames that insure perfect stability. You have carried their foundations by the most approved methods through thick layers of quicksand and clay down to rock bottom, and not satisfied with making them twenty stories high you undertake the construction of new ones that will have over forty stories. Where are you going to stop? There seems to be nothing in Nature to check your activity and your enterprise. You conquer every obstacle. You have built across your mighty rivers those wonderful bridges on the spans of which you have provided tracks for electric cars, wagon roads and walks for passengers on foot. Well, that seemed to be enough, yet you didn't think so, and not satisfied with your Brook-

Address of Welcome (continued).

lyn bridge and with the new suspension bridge, you determined to cross the rivers by means of tunnels located far below the level of their deep bottom, and you have succeeded, and they are there, your great tunnels, having your Imperial City as their center. I would never end if I were to mention the many wonders of your country in the vast field of engineering, yet I cannot stop without saying a word about the admirable institutions in which you train your engineers. I was fortunate enough to visit your special schools, your universities; I examined all their departments; I witnessed the work in their shops, in their laboratories; I attended their lectures, and I did not wonder any more at the splendid results of education and the instruction imparted in those centers of learning where, moreover, the visitor, if he be a foreigner, is always sure to be received with the utmost courtesy and given all the facilities to familiarize himself with the methods adopted. I cannot forget how I was received in the Universities of Pennsylvania, Lehigh, Columbia, Yale, Harvard, and Cornell, and in Stevens Institute, where many years ago I used to spend delightful hours in the company of Professor Morton; in the far-famed Boston Technical School; in old Rensselaer, and in many other places devoted to the teaching of those sciences without which no engineering education is complete. From this venerable hall which for a hundred years has been the meeting place of many illustrious men, from this sacred precinct, sacred to me with memories of past generations, I send my heartfelt thanks to those men who in those places received me and befriended and overwhelmed me with the most flattering and undeserved distinctions.

And now, my friends, after such a review of the great things of your glorious country, what can I show you in return? Well, I think I can say a few words for this country, whose citizens are glad to have you in their midst, and in saying that I do not fear to be blinded either by personal or national vanity, since I have reached that age at which men and things are seen as they really are, and appraised at their sterling worth. When the fire of our eyes is extinguished, but, instead of it, there is light; when, knowing that we are nearing our end, we do not any more live for ourselves, but for those who come after, applying to them and to us with great propriety the words of the Baptist, *"Oportet illium crescere, me autem minui,"* "It is proper for him to grow, for me to lessen."

Referring to things I would recommend you to examine while you are here, are some of the old buildings of which my friend, Mr. Morison, used to speak with such genuine enthusiasm in our

after-dinner conversations in Chicago ten years ago. He described them both with the accuracy of a man well posted in the sciences of construction, and with the *"amore"* of an artist whose soul had been enraptured by their beauty, and he often told the distinguished friends who had been sitting with us at the table that if the United States were the country of iron and steel constructors, well could Mexico boast of being the country of fine masonry work, showing plainly its Latin origin. I think that what Mr. Morison admired might be well worthy of your attention, and—pray mind it —I am not giving you my own opinion of our buildings, but I simply quote that which was expressed by one of your greatest and most highly respected engineers.

Passing to another kind of works, it would be worth while to study those built by the Spaniards for the water supply of the City of Mexico and some other cities; the former, at least, in what refers to old masonry aqueducts, do not exist any more, but when you were coming here your train passed under the lofty arches of Queretaro Aqueduct, built by Marquis de Villar del Aquila, a great benefactor of that city. Several others of the same kind might be cited, among them the Aqueduct of Cempoala and that of Las Remedios, not very far from the track of the National Railway.

Referring to works for irrigation, I might say we have some very remarkable ones which are almost unknown even to our people, and yet well worthy of attention by their proportions and by the clever way in which they were executed. There is among the excursions tendered you along the Mexican Railway, if you had time to stop at every point of it, you might admire the wagon roads, built in the colonial period, between Mexico and Vera Cruz, which are fine specimens of engineering ingenuity, and similar to them were the high roads, called "Royal Roads," leading north toward the principal cities of the country and west toward our seaports on the Pacific Ocean.

About our actual doings you may judge for yourselves; we will show them to you and give you all sorts of facilities for examining them. There are, within easy reach, the new water-works for our city, and their able director, by whom the original idea of utilizing for such purpose the springs of Xochimilco was first started, and by whom all the designs required for the execution of the work have been made, and who has given to it such splendid organization, is here at hand ready to answer any questions you may ask. He will supply you with an interesting pamphlet on the drainage of the City of Mexico and its sewerage. This great work was designed, as I have already told you, by one of our engineers, a member of your society, belonging also to our association, and whose well-

Address of Welcome (continued).

earned fame will survive him as long as the beneficial effects of his work are felt. You may depend upon him for any information you may require about his work.

Now, I could never finish if I were to mention all the new and great works carried out during the administration of General Diaz. He has been the creator of our railroad system. Under his rule, the Tehuantepec Railroad and its two great harbors have been executed, and this bridge of the world's trade is showing, even now, when it has just been opened, some of its future grandeur. Our Light-house Department has been created, and the illumination of our coast, on the Pacific, on the Gulf, and on the Caribbean Sea is nearly completed. New buildings, which would do honor to any country, like the new post office, the Palace for the Legislative Power, and for the Department of Communications and Public Works, have been erected or are in course of erection and pretty well advanced. There has not been, in the past thirty years, any international exhibition, be it in Europe or in the United States, where Mexico was not properly represented. And so it has been at the several Scientific Congresses held in the great capitals of the old and the new world. Our school system has received a powerful impulse, and the attendance of the classes is very striking. Our higher educational institutes are kept on the most liberal principles, and are also amply patronized. Mexico, in one word, has been doing wonderful work in a quiet way, without any puffing, doing it as the German poet says, *"Ohne Hast, ohne Rast, wie die Sterne."*

You are dealing at present in your country with some vital and most delicate questions, relating to the working of your railroads. Most intricate discussions have taken place between the National Government and the several companies, and nothing up to this time has been definitely settled. Here we do not experience such trouble, and we can never have it, thanks to the foresight of our executive and to the way in which concessions for railroads have been granted, putting them all exclusively under Federal Control and establishing on a well-defined basis the supreme authority of the National Government in all matters relating to the construction and the operation of the lines. Moreover, the great financial operations carried out recently so successfully by our Secretary of the Treasury, by means of which the National Government has acquired a controlling interest in our principal railroads, has solved beforehand a good many future difficulties, and has put in his hands this most powerful agent of modern, social and political life.

So it has been, to a certain extent, with the policy relating to our waters; concessions have been granted by the Department of Fomento for the utilization of our streams, and the result has been the erection of enormous power plants like those in the neighbor-

hood of Orizaba, in the State of Vera Cruz; the Portezuelo and Metepec, near Atlixco, Puebla; the Guanajuato Water and Electric Company, utilizing the waters of the River Duero, in the State of Michoacan, and herewith infusing new life into the legendary City of Guanajuato; and the colossal works of Necaxa, which you are invited to visit.

Some doubts were expressed not very long ago about the right of the Federal Executive to legislate on the question of water applied to irrigation, but now nobody would dare to take action after seeing the wonderful results brought about in the cotton region of the States of Durango and Coahuila—called the "Laguna"—by the regulations established by the National Government for the distribution of the waters of the River Nazas. A tract of land, sold fifty years ago for less than $80 000, could not be bought now for a hundred millions. New and powerful industries and new towns have sprung up in that region, where at present prosperity reigns supreme.

You will see during your stay here how safe our cities are, how life and property are protected all over our territory, and how absurd, not to say criminal, are those slanderous reports of plots started by our people against foreigners. The only foreigners in Mexico are bad men, and those we do not allow in our midst, whether they may have been born in Mexico or elsewhere. You will very likely be enabled on your return home to tell your friends that you met our President, God bless him, a President who goes wherever he likes by day or night, on foot, on horseback, or in his carriage, all alone, without ever having any guard or any escort or any policeman around him, not even when he goes to the mountains to indulge in his favorite sport, hunting, and when he stays for a week or two camping out, allowing everybody to admire his wonderful vigor and activity. As long as you are here try and do away with any prejudice you might have. Live our life as you breathe our air; get into our society, and you will see how kind and warm-hearted it is toward men of good will, and when you go back to your family and friends tell them what Mexicans really are, and how they practice hospitality.

Gentlemen of the American Society of Civil Engineers, since you honor us with your presence in this city, let me tell you that here when we meet a friend we do not confine ourselves to the somewhat cold and ceremonious handshaking of your country. We open our arms and press that friend against our breast so as to let him feel the beating of our heart. If you were to embrace the members of our profession gathered here to meet you, you would know by your own experience the warmth of their feelings and the sincerity of the welcome they tender you. May your short stay in this country be pleasant to you, and let us hope that our meeting may be fruit-

Address of Welcome (continued). ful and contribute to tighten the bonds of cordial and everlasting friendship, not only between individuals, but also between the United States and Mexico. And now I will say again, gentlemen, be welcome to this country, and God bless us all. (Applause.)

Reply to Address of Welcome. ONWARD BATES, VICE-PRESIDENT, AM. SOC. C. E.—Mr. Chairman, ladies and gentlemen: Our President, Mr. Benzenberg, expected to be with us to-night, but at the last moment was unavoidably detained, and I wish to express regrets that he is not here; I am sure that I express the regrets of all our members who are here, and my own in particular, because Mr. Benzenberg could have answered what has been said better than I can. It is a difficult matter for me to express properly our thanks this evening, which is my present duty, because the words would seem to fail me. We are very much honored to have you preside at our reception; we know of your high personal character and of the eminent service that you render your government as its Minister, and our hearts have been touched by our professional brother, Sr. Ibarrola. I hardly know how to respond to such expressions of friendship and esteem as he has made to us.

There are not as many members of the American Society of Civil Engineers here to-night as had been expected. The condition of the prosecution of the public works in the United States is such that it is very difficult for our members to get away for the three weeks' time that it requires to visit the City of Mexico, and a good many who had promised found themselves in the condition of Mr. Benzenberg, and had to give up their hopes and stay at home; nevertheless, we are a representative body, and we fairly represent our Society, I think. When we are at home we often hear the statement made that when you visit a Mexican gentleman in his home he makes you a present of his house and all that it contains. Now, we can readily appreciate that ourselves since we have arrived here. From the time we crossed the border and the Government permitted the Custom House officers to pass our luggage without examination, everything has been ours.

We have, first, to thank the officials for this beautiful hall in this stately building, "Mineria." To-day we owned about 200 miles of fine electric railway system with its 250 cars, more or less, of the most approved pattern, and at noon we took possession of the Country Club, where we dined on dishes that were as delicious as they were novel to us. To-morrow we expect to have the water-works in our possession, and I suppose as we go on from day to day taking over these valuable properties that are tendered us we shall ultimately acquire all the Republic of Mexico, with the Gulf of Mexico thrown in. I hope that this will not turn our heads with self-esteem, but rather that it will turn our hearts toward our friends who are so kind to us.

Mr. Chairman, I can scarcely find words to express our thanks for the kindness and more than kindness and attention which we have already received; we will have to try and show it in our actions.

The civil engineer is a soldier of peace; he is ready to give his services and his life for the good of his fellow men; it is the civil engineer who provides for the wealth of the nations and the comfort of mankind. He is sometimes also a soldier at war, because, when his country needs him, no man is more willing to give his services and risks his life for his country than the civil engineer, but in being a soldier of peace there is great distinction. The civil engineer serves the whole world; he is not limited to nationality; he goes where he is needed, wherever he can do good, and we have a common brotherhood. The American Society of Civil Engineers is a National Society, has members in every civilized nation on the face of the earth, and all its members are entitled to go where they are needed, into any nation whatever, to do their work. We come down here on this convention trip and we meet our brother engineers of the Republic of Mexico. Some of them are members of the Society and we feel entirely at home with them, and I am sure that each one of us reciprocates the friendship that Sr. Ibarrola has expressed in his address of welcome to-night, and when this trip is over and we go to our homes we will have at least learned one good Mexican word—the word *Amigo.* (Applause.)

Hon. Leandro Fernandez.—In the name of the Association of Engineers and Architects of Mexico, I now declare the Thirty-ninth Annual Convention of the American Society of Civil Engineers formally inaugurated, and open for the transaction of business.

BUSINESS MEETING.

Tuesday, July 9th, 1907, 8.30 P. M.

Onward Bates, Vice-Pres. Am. Soc. C. E.—Gentlemen of the American Society of Civil Engineers, I am calling you to order now for the first business meeting of the Society here. The first order of business is the report of the Secretary on the suggestions received from the membership as to the time and place for holding the next Annual Convention, and I ask the Secretary to read the report. Business Meeting called to order.

The Secretary read the following:

Report of the Secretary in Answer to Circular of Inquiry Concerning the Time and Place for Holding the next Annual Convention.

Convention of 1908.

"*To the Thirty-ninth Annual Convention, Mexico City:*

"In accordance with custom, and under instruction of the Board of Direction, the Secretary forwarded to each member of the Society on May 31st, 1907, a circular with return blank for suggestions

Convention of 1908 (continued).

as to the time and place for holding the next Annual Convention, and now reports the result of that circular.

"As to the place for holding the Convention.

"Total number of suggestions received, 520, as follows:

Denver, Colo	394
Boston, Mass	9
San Francisco, Cal	9
New York City	7
Pittsburg, Pa	6
Duluth, Minn	5
New Orleans, La	5
Seattle, Wash	5
Panama	5

"The following places have received four votes each:

Chicago, Ill.
Kansas City, Mo.
Mackinaw Island.
Quebec, Canada.
Saratoga, N. Y.

"The following places have received three votes each:

Atlantic City, N. J.
Montreal, Canada.
St. Louis, Mo.
Washington, D. C.

"The following places have received two votes each:

Cape, May, N. J.
Cincinnati, Ohio.
Colorado Springs, Colo.
Niagara Falls, N. Y.
St. Paul, Minn.
Watch Hill, R. I.
White Mountains.
Somewhere in District No. 1.
Region of Great Lakes.

"The following places have received one vote each:

Baltimore, Md.
Buffalo, N. Y.
The Catskill Mountains.
Chattanooga, Tenn.
Detroit, Mich.
Galveston, Tex.
Havana, Cuba.
Lake George, N. Y.
Manhattan Beach, N. Y.
Manila, P. I.
Middle States.
Milwaukee, Wis.
Minneapolis, Minn.
Montgomery, Ala.
Northern Part of Michigan.
Nova Scotia.
Portland, Ore.
Paris, France.
Philadelphia, Pa.
Sault Ste. Marie, Canada.
Steamer on Great Lakes.
Toronto, Canada.
Utica, N. Y.
Victoria, B. C.
Virginia Hot Springs, Va.

"As to the time for holding the Convention, the opinions of members differ widely, as the following list will show. Many of the answers specify the exact date or some week in the month given, but they have been classed under each month wherever possible:

January	has	2	votes	July	has	139	votes
February	"	1	"	August	"	16	"
March	"	2	"	September	"	23	"
May	"	8	"	October	"	2	"
June	"	126	"	November	"	1	"

"It will be observed that the only months not voted for are April and December.

"The following votes can only be classified generally. They are as follows:

January or February	1	Any time it will suit the Denver Engineers	1
March or April	1	In Dry Season	2
April or May	1	Some Summer Month	23
May or June	2	Early Summer	1
June or July	23	Mid-summer	1
July or August	14	Early Fall	1
August or September	1	Early Autumn	1
April or October	1	Winter	1
May or October	1	One year from 1907 Convention	1
June or October	1	Any time most convenient	1
June, July or August	1		
July, August or October	1		

"The number of members voting who seem to have no preferences as to time is 120.

"Respectfully submitted,

"CHAS. WARREN HUNT,

"*Secretary.*

"NEW YORK, July 2d, 1907."

THE CHAIRMAN.—What action will you take on this report, gentlemen?

Moved that it be referred to the Board of Direction with power. Seconded.

THE CHAIRMAN.—It is customary, gentlemen, that the opinion of the members be expressed in discussion of such a motion. Is there any discussion?

GARDNER S. WILLIAMS, M. AM. SOC. C. E.—I would like to say just a word, as endeavoring to speak for perhaps the younger members of the Society. Those of us here are certainly hardly a representative body of the rank and file of the organization, and I think it is quite important that, in selecting a place for the convention, we should bear in mind those who cannot afford to spend the time that must be taken to come here this time. There are many of us who enjoyed the convention last year, which, I am free to say, was to me the most enjoyable one I had attended up to that time; nevertheless, it must be realized that there is a very considerable portion of our members who would not feel warranted in attending a convention at such a location, and these are the members the Board of Direction should consider. I therefore think it is proper that a portion of the time, at least, the wishes of those members who are not able to travel far, but who wish to attend these conventions, should be considered, and I trust that such a view will be duly considered by the Board of Direction.

THE CHAIRMAN.—Is there any further discussion? There seems

Discussion on Convention of 1908 (continued).

to be no further discussion. All in favor of the motion will signify by saying aye. Contrary, no. The motion is carried.

THE CHAIRMAN.—The next order of business relates to the vacancy on the Nominating Committee due to the death of the late Charles Davis. The Secretary will make a report on the subject.

Report of the Secretary on the Vacancy on the Nominating Committee.

Vacancy in Nominating Committee.

THE SECRETARY.—The Secretary respectfully reports that Charles Davis, M. Am. Soc. C. E., who was appointed a member of the Nominating Committee, January 16th, 1907, died February 21st, 1907, causing a vacancy in the Nominating Committee.

The Secretary reported the facts in the case to the Board of Direction, and on March 5th, 1907, the Board passed the following resolution:

"That no action be taken by the Board to fill the vacancy, but the Secretary is instructed to notify the Business Meeting of the next Annual Convention of the vacancy, in order that action may be taken by the Society."

It should perhaps be explained that there seems to be no provision in the Constitution for filling a vacancy in the Nominating Committee. The only duties of the Board of Direction in relation to the appointment of this committee stated in the Constitution, are that it "shall, from time to time, divide the territory occupied by the membership into seven geographical districts," for the purpose of this Committee, "shall announce such division to the Society on or before the first day of May in each year, and may prescribe a mode of procedure for appointing this Committee"; but, apparently, the only way in which the appointment can be made is by the Annual Meeting each year. I do not know that I have made the matter clear, but it is a fact that the Board of Direction did not know what to do with this vacancy, or any way in which it could act.

MR. WILLIAMS.—Is it the view that this meeting can take any action?

THE SECRETARY.—It is not my view that it can, but the Board of Direction has directed me to report the case to this meeting for such action as is deemed proper. I presume any action can originate in either one of the two general meetings of the Society, but it is not so specified in the Constitution.

H. C. KEITH, M. AM. SOC. C. E.—I was going to ask how many there are on the Nominating Committee. As I remember it, the number is large enough so that the absence of one, or the reduction of the number by one, would not be serious, as it seems as

though we might wait until the January meeting for electing a successor.

THE SECRETARY.—There are nineteen, altogether; seven geographical districts, two representatives from each district, making fourteen, and the five last living Past-Presidents.

I have a letter, in that connection, Mr. President, from a Member of the Society, which perhaps it would be well to read. It is dated June 18th and is from Robert A. Cummings, M. Am. Soc. C. E. I explained to Mr. Cummings, as I have explained to this meeting, and received this answer:

"TUESDAY, JUNE 18th, 1907.

"MR. CHAS. WARREN HUNT, *Secy.*,
"American Society of Civil Engineers.
"220 W. Fifty-seventh St., New York, N. Y.

"DEAR SIR:—I thank you for your letter of the seventeenth in reference to the vacancy caused by the death of the late Mr. Charles Davis, who was a member of the Nominating Committee of this district. I desire to propose the name of Mr. Geo. Barnsley as a member of the Nominating Committee from this district to take the place of Mr. Charles Davis, deceased. I would ask that his name be presented at the Convention for action.

"Yours truly,
"ROBT. A. CUMMINGS."

WILLIAM B. FULLER, M. AM. SOC. C. E.—You didn't say what district this was.

THE SECRETARY.—District No. 4.

MR. KEITH.—I move that it is the sense of this Convention that no action be taken.

Motion seconded by Mr. Williams.

THE CHAIRMAN.—Any discussion on this motion? All in favor of it will signify by saying aye. Contrary, no.

Motion carried.

THE CHAIRMAN.—The next order of business will be the Report of the Special Committee on Rail Sections, and I ask the Secretary to make this report. **Report of Committee on Rail Sections called for.**

THE SECRETARY.—Mr. President: Since I left New York the following letters have been received.

"NEW YORK, July 1st, 1907.

"MR. CHAS. WARREN HUNT,
"Secr., Am. Society of Civil Engineers,
No. 220 West 57th Street, New York City.

"DEAR SIR:—I am sending you, herewith, copy of report of the Rail Committee, together with letter from Mr. Robert W. Hunt, Secretary of the Committee, which is self-explanatory in regard to the missing signatures.

"Yours respectfully,
"C. W. BUCHHOLZ,
"Consulting Engineer."

Discussion on receipt of Report of Committee on Rail Sections (continued).

"CHICAGO, June 24th, 1907.

"MR. R. MONTFORT, *Member, Rail Committee,*
"c/o Louisville & Nashville Ry. Co.,
"Louisville, Ky.

"DEAR SIR:—Enclosed you will please find the proposed report, which you will kindly sign and forward to Col. Prout, c/o Union Switch & Signal Co., Swissvale, Pa., with the request that he forward it after signing to Mr. Turner, whose address is 53 State St., Boston, Mass. You better give Mr. Prout Mr. Turner's address, as he may not know it, and I hope he will request Turner to forward it to Mr. Buchholz, c/o the Erie R. R. Co., New York, with the request that he send it to Secy. Hunt of the American Society.

"This will leave it short the signatures of Messrs. Carter and Roberts, but the latter is in Europe, and the former prefers not to sign the report, although he coincides with it; and as we are very anxious that Secretary Hunt should have it in time for the meeting of the Society in Mexico, it is important that the signatures should be rushed.

"Unfortunately, it was hung up from June 6th until a few days ago in Mr. Carter's office, owing to his absence on his line, and since that there have been one or two other delays, for which I assure you I have not been responsible.

"Asking you to kindly attend to this as promptly as you can, I remain,

"Yours truly,
"ROBERT W. HUNT,
"Secy., Special Rail Committee.

THE SECRETARY.—Before that Committee report is presented, it seems to be my duty to present certain facts, which are as follows: On January 17th, 1894, the Society, in Annual Meeting, adopted the following resolution:*

"*Resolved,* That reports of special committees upon engineering subjects shall be presented to the Secretary of the Society at least 30 days before their presentation to the Society at a business meeting, and shall be printed and sent out to the membership as soon thereafter as practicable, in the same manner as advance copies of papers are sent out, and with a proper cautionary notice that the report has not yet been presented to the Society, and is issued for the purpose of information and discussion only, with all rights of publication reserved."

The Board of Direction, on February 5th, 1907, instructed the Secretary to write to the Chairman of each of the Special Committees of the Society now in existence, calling attention to this resolution. The Secretary was further instructed to say that this rule would be enforced in the future in the matter of reports of Special Committees. All these facts were communicated to the Chairmen of the Special Committees on February 8th, 1907. This report, which has been received since our arrival in Mexico, cer-

* *Proceedings* Am. Soc. C. E., Vol. XX, p. 17.

tainly does not comply with that resolution which the Board of Direction has said would be enforced.

THE CHAIRMAN.—We cannot receive this report unless we rescind the action of the Society; and I would ask what is your pleasure; shall it lie over until the next Annual Meeting in January, or do you wish to take some other action regarding it? It is competent for this meeting to revise that action of the Society if it desires to do so.

IRA O. BAKER, M. AM. SOC. C. E.—I think I understand what the Board of Direction meant by its construction of the rules concerning the publication of reports, and perhaps it is unfortunate. Possibly it could not be helped that this report is not now in print, but is that sufficient reason why it should not now be presented to the Society? I think there are certain discussions going on that make it desirable that this report should be heard. Would this meeting be reflecting upon the Board of Direction if we should receive this report and discuss it if it is so desired?

THE CHAIRMAN.—I think, Professor Baker, that acting on this now would reflect on the resolution of the Annual Meeting of the Society; it would be acting contrary to a rule that has been established, and I do not see how we can receive the report and consider it, unless we pass a resolution of the Society in this general meeting which will cancel the former action. We can do so, as I understand it, and then do what we please with the report.

A MEMBER.—Was the resolution of the Annual Meeting that the reports should be published or was it calling the attention of the Board of Direction to a former action? Will the Secretary state?

THE SECRETARY.—The original resolution, Mr. Chairman, was adopted by the Society in Annual Meeting on January 17th, 1894, and still remains on the books; it has not been cancelled. That is the highest authority we have in the Society.

A MEMBER.—Has it been lived up to always?

THE SECRETARY.—No, sir.

A MEMBER.—That is an important point on this occasion.

THE SECRETARY.—I think it is the fact that it has not been lived up to that caused the Board to take its action in notifying each of the committees that in future it would be lived up to.

A MEMBER.—But might it not be unfair to a committee of busy men to notify them, say, the first of March, that the Society was going to live up to a law that had been a dead letter for thirteen years? It seems to me that we are hardly treating our committee right to be so peremptory in reviving a dead law.

THE CHAIRMAN.—I think, in answer to that question, that it would be perfectly fair, and I doubt that we can admit that that is a dead law. There is a way which has been suggested by which we

Discussion on receipt of Report of Committee on Rail Sections (continued).

can act on this report, but unless that way is taken I should certainly rule that we cannot act without a new resolution to take the place of the one which now controls in the matter.

A MEMBER.—I move that the report be received as information and discussed accordingly.

MR. WILLIAMS.—I think this motion has not been seconded, and I would move that the resolution of the Annual Meeting of 1894 be reaffirmed by this meeting.

CHAS. B. BALL, M. AM. SOC. C. E.—I second the motion.

THE CHAIRMAN.—The motion is before us that the resolution referred to be reaffirmed, and it is open for discussion. Is there any discussion on this motion? I do not know that I am competent to rule on that, but it does not seem to me that the motion is in order, for if it is, and it is carried, the matter will be left just where it was, and if it is not carried it leaves the matter where it was.

A MEMBER.—I am not particularly interested in rail sections, but if there is any person here who is, I will just say a word or two. At a meeting of the American Railway Engineering and Maintenance of Way Association, at Atlantic City, they had a very interesting discussion with relation to rail sections, and it seems to me that the present is a proper time to hear something from the report of the American Society of Civil Engineers also; it seems to me a shame to delay this report for six months or a year, and I should like to see some way out of the difficulty, so that the matter in the report would get in print.

A MEMBER.—Is there a motion before the meeting?

THE CHAIRMAN.—The motion before the meeting is that the resolution referred to, requiring thirty days' notice of a report of a Special Committee and its printing and distribution among members, be reaffirmed.

A MEMBER.—It is my impression that the proper thing to do would be to move that that report be received and printed, as far as the proceedings of this meeting are concerned. If I understand the motion that was made several years ago and adopted, it was at least thirty days. By printing the report as a part of the proceedings of this meeting we give them six months instead of thirty days. I will not make a motion, as there is already one before the meeting, but it seems to me that that is what ought to be done.

MR. WILLIAMS.—It seems to me that there is a decided difference between printing the report in the proceedings of this meeting and printing it for distribution for the members, and I hardly think we ought to print that report and thereby take formal action of the Society until it has been sent out to members, and they have had an opportunity to read it. That is the very thing I wish to head off. This report should not become a part of the proceedings of the

Society until it has been submitted, in the preliminary manner provided, to the membership thereof, and for that reason I certainly hope that such a motion or action as has been suggested will not be taken at this time. The suggestion has been made that we might receive the report informally, have it read and discussed informally, and that no record of that discussion should appear upon the minutes, and that thereafter the report be printed for distribution. If such a method of procedure would meet with the approval of a considerable number here I would be glad to withdraw the motion I have made, but I would like to hear expression of opinion now upon it before doing so.

J. L. Campbell, M. Am. Soc. C. E.—It appears to me that the suggestion made by Mr. Fuller and the gentleman who followed him is not a very good one. Possibly I didn't understand the reading of the resolution right; but, as I understand it, I see no reason why this report could not be read here in this meeting and, if the members desire, be discussed. That will not mean that the Society will have to take any decisive action in the way of accepting or rejecting the report at this time. It would have the effect, however, of presenting to us at the present time the conclusion of this Committee, and, as has been very truly said, this is an important subject, and any discussion of it is pertinent at the present time, and it does look too bad to have this whole thing laid over for twelve months without our knowing anything about what the Committee has recommended.

Mr. Keith.—This is a matter in which I am personally very much interested, although not directly connected with rail work, but when I think of the small number here at this Convention compared with the great number of those who are intensely interested in this subject and who are not present, it seems to me that it is hardly fair to the absent members of the Society that we should receive the report and have its first discussion here without giving them an opportunity. I think that the resolution that was passed thirteen years ago was a good one. I remember the intense excitement that existed at the time that resolution was passed, and it was because of a case somewhat like this, if I remember rightly, that it was passed. It seems to me that it is better that the matter should lay over until the regular time. I am very sorry that this is necessary, because I think that this is an opportune time for the presentation of such a report, but can we do it in fairness to those who are not present at this Convention? I think not.

Mr. Fuller.—I would like to ask if, in the ordinary course of business, the Secretary would not send out this report now within, say, the next month. If that is the case it seems to me that it covers the point of getting the publication before the members.

Discussion on receipt of Report of Committee on Rail Sections (continued).

THE SECRETARY.—I cannot say that I would do it within the next month, because I may not be able to do it, but certainly within the next two months. I think perhaps it may throw some light on the subject to say that when this original resolution was passed we did not have the same system of publications that we have now. In 1894 we did not publish advance copies of papers in the form of *Proceedings,* hence all such reports had to be sent out in the form of advance copies. If this report were received at this meeting it would probably be published in the August number of *Proceedings.* and if this meeting were to take action, not necessarily a final action, in accepting or even in receiving it, and would pass a resolution that this report be brought up for action at the next Annual Meeting, it would seem that it might be advantageous to have it discussed here, and would not be in any way objectionable. The original resolution, as Mr. Keith very justly states, was passed because a report was brought in at the last minute, and this was objected to by members of the Society who had had no opportunity of seeing it before it was presented to the meeting, and who were therefore not prepared to take up the discussion. It seems to me with our present method, in which discussions on papers or reports of Committees are continued from month to month, that discussions on this report could be printed, and the whole matter taken up at the next general meeting.

MR. WILLIAMS.—I would like to move as a question of privilege that an invitation be extended to the members of the Mexican Society of Engineers and Architects to unite with the American Society of Civil Engineers in their meetings and join in the discussion.

THE SECRETARY.—I may say that that was done some two or three months ago.

MORRIS R. SHERRERD, M. AM. SOC. C. E.—I would move as a substitute to Professor Williams' motion, if it be entertained by the Chair, that the report of the Rail Committee be read and discussed, and printed in the *Proceedings,* provided that no action be taken on said report until the Annual Meeting.

MR. WILLIAMS.—I would be glad to accept that substitute if the seconder is agreeable.

MR. BALL.—That is agreeable to me, but while I am on my feet I would like to say that I recall exceedingly well the line of discussion referred to in 1894 when this matter was taken up; it was thought that, in justice to absent members, the report could not be received for discussion without having been previously printed, but this present occasion seems to justify an exception to that course, however, I feel sure that the action taken at that time should be sustained and should be enforced by the Board of Direction.

MANSFIELD MERRIMAN, M. AM. SOC. C. E.—Let us consider what was the purpose of this resolution. It was not to prevent the presentation of reports to the meetings of the Society, and their publication, but it was to prevent hasty and ill-advised discussion. As the rule has been repeatedly violated in the past, it seems that this Business Meeting would not go far wrong if it were to permit this report to be received and read, and to be printed and distributed as soon as possible. The subject of rail sections is one to which I have given some little attention, but I am sure I would not care to discuss the matter until I had carefully read the report of the Committee.

THE CHAIRMAN.—I would ask Mr. Williams to state the motion as he has accepted it, as it has been revised.

MR. WILLIAMS.—That substitute has been accepted by the mover of the original motion and by its seconder.

THE CHAIRMAN.—The original motion was that the former motion be reaffirmed.

MR. SHERRERD.—I offered a substitute which the mover of the original motion has accepted.

THE CHAIRMAN.—State it.

Resolution on Receipt of Report of Committee on Rail Sections.

MR. SHERRERD.—I moved that the report of the Committee on Rail Sections be read and be open for discussion, and printed in the *Proceedings*, provided no action thereon shall be taken until the next Annual Meeting.

THE SECRETARY.—If I might suggest, "and that it shall be made an order of business for the next Annual Meeting."

MR. SHERRERD.—Yes; that it shall be made an order of business.

THE CHAIRMAN.—That, gentlemen, is the motion which is before the meeting. Is there any discussion on it as you have heard it?

MR. KEITH.—It seems to me that in simply hearing a report on so important a matter as this, we cannot sufficiently adjust it to make the discussion all that would be desirable—that the first discussion of the subject should be—and therefore I would oppose it.

MR. SHERRERD.—My thought in suggesting that it be discussed is that, if any members of the Society who are here care to discuss any of its features, that discussion may go out with the report. Of course, any written discussion, either from those who are here or from those who may care to discuss it, can immediately be sent to the Secretary after the publication of *Proceedings*, and such discussion will, I believe, be printed before the Annual Meeting. Will they not, Mr. Secretary?

THE SECRETARY.—Yes.

MR. SHERRERD.—The discussions that may be received prior to the Annual Meeting will then be presented, and it will bring the whole subject before the Society in a shape in which the views of members can be ascertained by the membership at large.

THE CHAIRMAN.—Is there any further discussion on this, gentlemen? Then I will put the question. All those in favor of the motion will signify by saying aye. Contrary, no. The motion is carried.

The Secretary read the following report:

Progress Report of the Special Committee on Rail Sections.

Report of Committee on Rail Sections.

"GENTLEMEN:—Your Committee respectfully report that they have given the report, which they submitted under date of January 17th, 1906, and which was referred back to them, careful consideration, and would now report that they are in consultation with committees representing other societies and organizations, as well as other interested parties, on the subject of modified rail sections, with the purpose of preparing and submitting to your Society a new series of such sections.

"In this designing of heavier sections, particular attention is being given to the advisability of increasing the percentage of metal in the webs and flanges, as compared with the existing sections recommended by your Society.

"This they hope to accomplish in due time, and in the meantime respectfully submit to the Society for its consideration the following specifications for the manufacture of Bessemer and Open-Hearth rails:

"RECOMMENDED SPECIFICATIONS FOR BESSEMER STEEL RAILS.

"*Process of Manufacture.*—The entire process of manufacture and testing shall be in accordance with the best state of the art, and the following instructions shall be faithfully executed:

"Ingots shall be kept in a vertical position in the pit heating furnaces until ready to be rolled, or until the metal in the interior has had time to solidify.

"No bled ingots shall be used.

"There shall be sheared from the end of the blooms formed from the top of the ingots not less than twenty-five per cent., and if, from any cause, the steel does not then appear to be solid, the shearing shall continue until it does. If, by the use of any improvements in the process of making ingots, the defect known as piping shall be prevented, the above shearing requirements may be modified.

"The number of passes and speed of train shall be so regulated that on leaving the rolls at the final pass, the temperature of the rail will not exceed that which requires a shrinkage allowance at the hot saws, for a 33-ft. rail of 100-lb. section, of $6\frac{7}{16}$ in., and $\frac{1}{16}$ in. less for each 5-lb. decrease of section. These allowances to be decreased at the rate of $\frac{1}{100}$ in. for each second of time elapsed between the rail leaving the finishing rolls and being sawn. No artificial means of cooling the steel shall be used after the rails leave the rolls, nor

shall they be held before sawing for the purpose of reducing their temperature.

"Chemical Composition.—Rails of the various weights per yard specified below shall conform to the following limits in chemical composition:

	70 to 79 lb. Percentage.	80 to 89 lb. Percentage.	90 to 100 lb. Percentage.
Carbon	0.50 to 0.60	0.53 to 0.63	0.55 to 0.65
Phosphorus shall not exceed	0.085	0.085	0.085
Silicon " " "	0.20	0.20	0.20
Sulphur " " "	0.075	0.075	0.075
Manganese	0.75 to 1.00	0.80 to 1.05	0.80 to 1.05

"Drop Test.—One drop test shall be made on a piece of rail, not less than 4 ft. and not more than 6 ft. long, selected from each blow of steel. The test piece shall be taken from the top of the ingot. The rails shall be placed head upward on the supports, and the various sections shall be subjected to the following impact tests under a free falling weight:

70 to 79-lb. rails..........................	18 ft.
80 to 89-lb. rails..........................	20 "
90 to 100-lb. rails..........................	22 "

"If any rail breaks, when subjected to the drop test, two additional tests may be made of other rails from the same blow of steel, also taken from the top of the ingots, and if either of these latter rails fail, all the rails of the blow which they represent will be rejected, but if both of these additional test pieces meet the requirements, all the rails of the blow which they represent will be accepted.

"The drop-testing machine shall have a tup of 2 000 lb. weight, the striking face of which shall have a radius of not more than 5 in., and the test rail shall be placed head upward on solid supports 3 ft. apart. The anvil block shall weigh at least 20 000 lb., and the supports shall be part of, or firmly secured to, the anvil. The report of the drop test shall state the atmospheric temperature at the time the test was made.

"Section.—The section of rail shall conform, as accurately as possible, to the templet furnished by the railroad company, consistent with the paragraph relative to specified weight. A variation in height of $\frac{1}{64}$ in. less, or $\frac{1}{32}$ in. greater than the specified height, and $\frac{1}{16}$ in. in width will be permitted. The section of rail shall conform to the finishing dimensions.

"Weight.—The weight of the rails will be maintained as nearly as possible, after complying with the preceding paragraph, to that specified in contract. A variation of one-half of 1% for an entire order will be allowed. Rails will be accepted and paid for according to actual weights.

"Length.—The standard length of rails shall be 33 ft. Ten per cent. of the entire order will be accepted in shorter lengths varying

Report of Committee on Rail Sections (continued).

by even feet to 27 ft., and all No. 1 rails less than 33 ft. long shall be painted green on the ends. A variation of ¼ in. in length from that specified will be allowed.

"*Drilling.*—Circular holes for splice bars shall be drilled in accordance with the specifications of the purchaser. The holes shall conform accurately to the drawing and dimensions furnished, in every respect, and must be free from burrs.

"*Straightening.*—Care must be taken in hot-straightening the rails, and it must result in their being left in such condition that they shall not vary throughout their entire length more than 5 in. from a straight line in any direction, when delivered to the cold-straightening presses. Those which vary beyond that amount, or have short kinks, shall be classed as second-quality rails and be so stamped.

"Rails shall be straight in line and surface when finished—the straightening being done while cold—smooth on head, sawed square at ends, variation to be not more than $\frac{1}{32}$ in., and, prior to shipment, shall have the burr occasioned by the saw cutting removed, and the ends made clean. No. 1 rails shall be free from injurious defects and flaws of all kinds.

"No. 2 rails shall be accepted up to 5% of the whole order. They shall not have flaws in their heads of more than ¼ in., or in the flange of more than ⅛ in. in depth, and, in the judgment of the inspector, these shall not be so numerous or of such a character as to render them unfit for recognized second-quality rail uses. The ends of No. 2 rails shall be painted white, and shall have two prick-punch marks on the side of the web near the heat number brand, and placed so as not to be covered by the splice bars. Rails from heats which failed under the drop-test shall not be accepted as No. 2 rails.

"*Branding.*—The name of the maker, the weight of the rail, and the month and year of manufacture, shall be rolled in raised letters on the side of the web; and the number of the blow shall be plainly stamped on each rail where it will not subsequently be covered by the splice bars.

"*Inspection.*—The inspector representing the purchaser shall have free entry to the works of the manufacturer at all times when the contract is being filled, and shall have all reasonable facilities afforded him by the manufacturer to satisfy him that the finished material is furnished in accordance with the terms of these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment.

"The manufacturer shall furnish the inspector, daily, with carbon determinations for each blow, and a complete chemical analysis every 24 hours, representing the average of the other elements contained in the steel, for each day and night turn. These analyses shall be made on drillings taken from small test ingots. On the request of the inspector, the manufacturer shall furnish drillings for check analyses.

"*For Basic Open-Hearth Rails.*—The specifications for rails made by the Basic Open-Hearth process shall be the same as for Bessemer rails, excepting that a full chemical determination shall be furnished

for each heat and two drop tests from each. Their chemical composition shall be:

	70 to 79 lb. Percentage.	80 to 89 lb. Percentage.	90 to 100 lb. Percentage.
Carbon	0.53 to 0.63	0.58 to 0.68	0.65 to 0.75
Phosphorus shall not exceed	0.05	0.05	0.05
Silicon " " "	0.20	0.20	0.20
Sulphur " " "	0.06	0.06	0.06
Manganese	0.75 to 1.00	0.80 to 1.05	0.80 to 1.05

"Respectfully submitting the above report, we remain,

"JOSEPH T. RICHARDS, *Chairman;*
"CHAS. W. BUCHHOLZ,
"S. M. FELTON,
"JOHN D. ISAACS,
"R. MONTFORT,
"H. G. PROUT,
"GEO. E. THACKRAY,
"E. K. TURNER,
"WM. R. WEBSTER,
"ROBERT W. HUNT, *Secretary.*"

THE CHAIRMAN.—You have heard the report of the Committee on Rail Sections. This is open to discussion, but not for any action before this meeting. Is there any discussion on this report?

Is there any new business before the meeting? Nothing being moved, I will state that this completes the business for the day.

I will ask the Secretary to make some announcements.

The Secretary and Mr. Moler made announcements as to the programme for the next day, and also for the remainder of the time which the members will spend in Mexico.

Adjourned.

THIRTY-NINTH ANNUAL CONVENTION.

EXCURSIONS AND ENTERTAINMENTS.

The arrangements for the Convention were in the hands of the following Committees:

Committee of the Board of Direction.

A. L. Bowman
J. Waldo Smith
Chas. Warren Hunt

Local Committee of Arrangements.

William G. Moler

John B. Body
T. A. Corry
E. H. Drury
S. J. Fortin
Roberto Gayol
Lewis Kingman

Entertainment at St. Louis.

A special train, to leave St. Louis on the morning of July 4th, 1907, had been arranged for, and the Engineers' Club of St. Louis, through its President, Mr. E. R. Fish, kindly invited all those who arrived in St. Louis on the evening of July 3d to a dinner at the Cherokee Garden. Accordingly, at 7.30 P. M., special cars were waiting for the party at the Southern Hotel, and, accompanied by a committee of the hosts, a special run was made to the place of entertainment. Here a most delightful social evening was passed, and the return made to the Hotel by special cars. This entertainment, which was held in the open air, made a very agreeable break in a somewhat long journey.

Arrival in Mexico City.

Sunday, July 7th, 1907.—The special train was scheduled to arrive in the City of Mexico on the evening of Saturday, July 6th, but the schedule was not adhered to by the railroads, and the party did not reach Mexico City until about midday on Sunday, July 7th. Notwithstanding the uncertainty of the time of arrival, the party was met by representatives of the various engineering organizations and of the Government, and given a most hearty welcome, the effect of which was not lessened by the presence at the station of a fine military band which rendered a number of American national airs.

Excursion about Mexico City.

Monday, July 8th, 1907.—At 9 A. M. the party met at the Mineria (Engineers' School and Mines Building), which, through the

courtesy of Hon. Leandro Fernandez, Minister of Public Works, was placed at the disposal of the Society for Headquarters, meeting room, etc., and, taking the seven waiting special trolley cars, as guests of the Street Railway Company of Mexico, Mr. R. C. Brown, General Manager, visited a number of the suburbs of the City, passing through Zocalo, and thence to Guadalupe where the party remained an hour, thence returning *via* Zocalo, and running out to Tlalpam, one of the beautiful suburbs, where about half an hour was spent. After leaving Tlalpam, the excursion reached Churubusco, where the entire party, which included not only the American visitors but many members of Mexican engineering organizations and their ladies, and numbering about 300, was entertained at luncheon, which occupied about two hours, after which the cars were again boarded, and the trip continued to San Angel, *via* Coyoacan, thence to Chapultepec, and to the Power-House of the Street Railway Company, returning after that to the starting point at the Mineria.

New City Water-Works.

Tuesday, July 9th, 1907.—A start was made from the Mineria by special cars at 8.30 A. M., and the route lay *via* Zocalo to Chapultepec, where the reservoirs were inspected, after which a special train was boarded for the run to Xochimilco. Stops were made at frequent intervals for the inspection of the new concrete aqueduct.

Xochimilco, where one of the springs forming the source of supply is located, was reached at 1.30 P. M., and luncheon was served in a shelter beautifully decorated with floral emblems for the occasion. The hosts of the day were the Water-Works Commission, and the Chief Engineer of the Works, Manuel Marroquin, M. Am. Soc. C. E. The return was made to Chapultepec at 6 o'clock, where the electric car specials awaited the party for the return to the Mineria.

Meetings of the Society.

Wednesday, July 10th, 1907.—The day was devoted to meetings for the discussion of professional topics. Three meetings were held.

Trip to Necaxa.

Thursday. July 11th, 1907.—By invitation of the Mexican Light and Power Co., Ltd., Mr. R. F. Hayward, General Manager, the members of the Society, and other guests, met at the station of the Hidalgo and Northeastern Railroad at 6.30 A. M., where a special train was waiting for the run to Carmen, the first camp of the Company. Breakfast was served on the train, and lunch was served at Carmen, after which a train of flat-cars, on which careful

preparations had been made for the seating of the party as well as for their protection from the rain which is at times almost inevitable in this locality, was boarded. The trip from Carmen to Necaxa (about 29 km.) was over the Company's narrow-gauge railroad, and afforded during its whole length views of some of the most beautiful mountain scenery in Mexico. Necaxa was reached about 4 P. M., and those who were adventurous enough started to inspect the work in progress, notwithstanding the rain.

After dinner had been served, an informal dance was organized in which all participated.

Friday, July 12th, 1907.—The morning was spent in the inspection of the dam, which is being built at Necaxa by the hydraulic-fill process, and of the pressure pipe line and power-house. All the party visited the power-house, some going down and up in the cages while others rode down and up the trail on horseback. Luncheon was served at Necaxa, and the party arrived in Mexico at 11 P. M.

The total number on this trip was about 110.

Reception by President Diaz.

Saturday, July 13th, 1907.—Meeting at the Mineria at 8.30 A. M., the party took special cars for the National Palace where at 9.30 they were received by His Excellency, Porfirio Diaz, President of the Mexican Republic, the party being introduced by Hon. Leandro Fernandez, Minister of Public Works, in a short speech, which was responded to by the President, who welcomed the party to Mexico and who expressed his pleasure at seeing them.

At 1 P. M., the party was entertained at a banquet at Chapultepec by the Society of the Military College and the Mexican Association of Engineers and Architects. Many distinguished Mexican engineers, both civil and military, were present. Music was furnished for the occasion by two bands, and addresses were made by Señor Ignacio de la Barre, President of the Military College, and Señor J. Ramón Ibarrola, representing the Mexican Association of Engineers and Architects, and by Onward Bates, Vice-President, Am. Soc. C. E.

In the evening, the Annual Session of the Society of the Military College was held in the Mineria, the entire building being specially decorated and illumined for the occasion. This meeting was dedicated to the American Society of Civil Engineers, and Onward Bates, Vice-President, Am. Soc. C. E., presided as Honorary President. At this meeting, addresses were made by Brig.-Gen. Beltran, Director of the National Military College, Señor Roberto Dominguez, Postmaster-General of Mexico, and

Señor Luis G. Leon. In addition to the speechmaking, three musical numbers were rendered by the Artillery and Police bands.

After the meeting an elaborate supper was served on the balcony of the patio of this beautiful building.

Sunday, July 14th, 1907.—Facilities were furnished by the Local Members for all members of the party to visit the French celebration of the Fall of the Bastile, and an exhibition of the Spanish game of Pelota.

Excursion to the Drainage Works.

Monday, July 15th, 1907.—The party met at the Mineria at 6.30 A. M., and proceeded by special trolley cars to the Peralvillo Station of the Hidalgo and Northeastern Railway. Thence, as guests of the Mexican Government, the party boarded a special train, made up for the occasion, and started at 7.30 A. M. for the inspection of the Drainage Works of the Valley of Mexico. A stop of nearly an hour was made for the inspection of the sluice gates of Lake Texcoco, after which stops were made at San Cristobal, at the bridge of San Pedro, at Shaft No. 1, and at the entrance to the Drainage Tunnel at Tequixquiac. At the last stop an elaborate banquet, presided over by Señor Ibarrola, was served, and the special train started on the return at 4 P. M. reaching the Hidalgo and Northeastern Station in Mexico at about 8 P. M.

At 10 P. M. the party again took cars at the station of the Mexican Railway and started for a trip to Orizaba.

Trip to Orizaba.

Tuesday, July 16th, 1907.—The special train, which was kindly furnished through the courtesy of the Mexican Railway, reached Esperanza early in the morning, and members of the party were entertained at breakfast in the station by the Mexican membership, after which the trip was resumed in an observation train, Orizaba being reached at 11 A. M. After a short stop, the train proceeded as far as Fortin, where the coffee groves and banana plantations, and the hacienda of Las Animas were visited. Returning, no stop was made at Orizaba, but the train was run back to Rio Blanco, where luncheon was served in the Assembly Hall of the Compañia Industrial. After luncheon the party visited the cotton mills, but owing to the lateness of the hour and to the inclemency of the weather, a visit to the town of Orizaba, which had been planned, was abandoned. The party left Rio Blanco at 4 P. M., arriving at Esperanza in time for dinner, and leaving there at 10.30 P. M. for the return trip to Mexico, which was reached at 5.30 A. M., Wednesday, July 17th.

Excursion to Cuernavaca.

Wednesday, July 17th, 1907.—Without returning to their hotels, the party took breakfast at the Mexican station, and began the trip to Cuernavaca (as guests of the Mexican membership of the Society) at 7 A. M. On arrival at Cuernavaca, lunch was served at the Hotels Bella Vista and Morelos, and after visiting the many points of interest, the return was made to Mexico in the late afternoon.

Special Trip to the Isthmus of Tehuantepec.

A party of eighteen accepted the kind invitation of Messrs. S. Pearson and Son, Ltd., to be their guests on a trip to visit the Port Works, now under construction on the Isthmus of Tehuantepec. This party left the main party on Tuesday afternoon at Rio Blanco. A special car having been placed at their disposal, A. Peimbert, M. Am. Soc. C. E., acting for the hosts, took charge of the party. The car left Rio Blanco at 3.30 P. M., and was run to Orizaba where, under the guidance of S. W. Stacpoole, M. Am. Soc. C. E., two or three hours were agreeably spent in seeing this beautiful town. The night was spent in the car at Cordoba, and the next morning the journey was resumed over the Vera Cruz and Pacific Railroad, Tierra Blanca being reached by midday. Here it was ascertained that excessive rains had caused a washout farther down the line, which made a delay of 24 hours necessary, and, to occupy this time, the car was run from Tierra Blanca to Vera Cruz, which was reached in time to give ample opportunity to see this interesting place. In the morning, the trip was resumed, and, after one more night spent on the road, Santa Lucretia, on the Tehuantepec Railroad, was reached on the morning of Friday. Coatzacoalcos was reached in the early afternoon of Friday, July 19th, and the party was here met by the engineers and other officers of the Company, and work in progress was inspected during the afternoon. The entire party was entertained at dinner, and on the morning of Saturday, July 20th, the trip from Coatzacoalcos across the Isthmus was begun, Tehuantepec being reached in the early afternoon. The balance of the day, and the morning of Sunday, was spent in this very interesting Indian town, and Salina Cruz was reached at midday. Here again special preparations had been made for the inspection of the extensive Port Works, and the afternoon was devoted to this purpose. In the evening the return trip was started, Cordoba being reached in the late afternoon of Monday, July 22d. This gave an opportunity of visiting, both in the afternoon and in the early morning, this beautiful town, and the return trip was made without accident to the City of Mexico, which was reached in the evening of Tuesday, July 23d.

Those whose privilege it was to make this trip were delighted with it. The weather was very good at all times, and never excessively hot. This was a most agreeable surprise, as all had been led to believe that the trip at this season would be uncomfortable and probably dangerous to health. No inconvenience whatever was had from mosquitoes, the arrangements for the care of the party were perfect, and the works visited (the Tehuantepec Railroad, as well as the Port Works at each end) were found of great interest.

Acknowledgment of Courtesies.

It has been impossible to give in detail in this account the many courtesies to the Society as a whole, or to indicate the many personal kindnesses received by individual members during this Convention. There was such hearty co-operation in the welcome, and in the preparations made for the entertainment and instruction of the visiting party, that it has been impossible to acknowledge each particular courtesy extended. It is therefore felt that a general acknowledgment should be here made to every one who assisted in the entertainment, on behalf of the Society as a body, and of all those who were fortunate enough to be able to attend this Convention.

Among those to whom special acknowledgment is due are the following:

To President Porfirio Diaz, for his cordial welcome, and for the interest manifested by him in the visit of the Society to Mexico;

To the Mexican Society of Engineers and Architects, and to Señor Leandro Fernandez, its President;

To the Society of the Military College, and to Señor Ignacio de la Barre, its President; and also to Señor Joaquin Baltran, Director.

To the Sociedad "Antonio Alzate";

To the St. Louis Engineers' Club, M. E. R. Fish, President, for a very pleasant evening spent in St. Louis, *en route* for Mexico;

To the Electrical Street Railway Company of Mexico (Mr. R. C. Brown, Gen. Mgr.), for its courtesy in issuing to every member of the party a special pass good at all times on any of its cars, from the arrival of the party in Mexico until August 1st; as well as for the special cars furnished every day during the stay of the party in the City;

To the Water-Works Commission of the City, Manuel Marroquin, M. Am. Soc. C. E., Chief Engineer, for the interesting visit to the work in progress, and for the delightful banquet at Xochimilco;

To the Mexican Light and Power Company, Ltd., R. F. Hayward, M. Am. Soc. C. E., Gen. Mgr., for the two days' excursion to its interesting works at Necaxa;

To the Mexican Railway, and to Mr. Walter Morcom, for free transportation on the trip to Orizaba, and for other courtesies extended;

To the Mexican Central Railway, and to Mr. C. R. Hudson;

To the American, British, Spanish, and Country Clubs, of the City of Mexico, for their hospitality to all the visiting members;

To the Hydrographic Commission of the Republic of Mexico, and to Señor J. Ramón Ibarrola, Director, for the interesting excursion to the drainage works of the Valley;

To S. Pearson and Son, Ltd., John B. Body, M. Am. Soc. C. E., Director, for the very interesting seven-day trip to the Isthmus of Tehuantepec;

To all members of the Society residing in Mexico who aided so much in the entertainment of the visiting members, and last, but by no means least, to the Local Committee of Arrangements, who planned so carefully, and executed so well, the whole delightful programme.

M 10 U

THE ATTENDANCE AT THE THIRTY-NINTH ANNUAL CONVENTION.

The following 84 members were in attendance:

Adam, Robert .....Mexico City
Adams, Frederick, Salina Cruz, Mexico
Alvord, John W...Chicago, Ill.
Anderson, J. T. Noble, Belfast, Ireland
Andrews, Horace..Albany, N. Y.
Archbald, James..Scranton, Pa.

Baker, Ira O..Champaign, Ill.
Baldwin, W. J..New York City
Ball, Charles B....Chicago, Ill.
Bates, Onward.....Chicago, Ill.
Bayliss, J. Y....St. Louis, Mo.
Beach, L. H., Fort Leavenworth, Kans.
Bienenfeld, Bernard, San Francisco, Cal.
Blackford, F. W...Mexico City
Body, J. B........Mexico City
Bowman, A. L..New York City
Breuchaud, Jules, Park Hill, N. Y.
Buxton, Clifford..Toledo, Ohio

Campbell, J. L....El Paso, Tex.
Clayton, R. M.....Atlanta, Ga.
Coe, D..Rincon Antonio, Mexico
Connor, E. H., Leavenworth, Kans.
Cook, John H..Paterson, N. J.
Corry, T. A.......Mexico City
Crowell, Francis S., Purcell, Ind. T.

Deyo, S. L. F..New York City

Earley, J. E.......Mexico City

Follet, W. W....El Paso, Tex.
Fortin, S. J.......Mexico City
Freeman, John R., Providence, R. I.
Frisell, E. H......Mexico City
Fuller, W. B....New York City

Gardiner, J. P....Indé, Mexico
Gardner, W. M..Memphis, Tenn.
Gayol, Roberto....Mexico City
Greene, A. E..Ann Arbor, Mich.

Hallsted, James C..Chicago, Ill.
Henderson, S. W..Durango, Col.
Hill, Walter A., Churubusco, Mexico
Hitchman, J. C..Ocatlan, Mexico
Hodge, Henry W., New York City
Holmes, E. M..Daiquiri, Cuba
Howe, J. M......Houston, Tex.
Hunt, Charles Warren, New York City
Hyde, A. Lincoln, Columbia, Mo.

Jonah, F. G..New Orleans, La.

Keith, Herbert C., New York City
Kerr, Frank M., New Orleans, La.
Kingman, Lewis...Mexico City

Leonard, H. R..Philadelphia, Pa.
Lewis, Nelson P..New York City
Lewis, Sidney F., New Orleans, La.
Lynch, M. L........Tyler, Tex.

McCurdy, John E., Oaxaca, Mexico
Marroquin y Rivera, M., Mexico City

Mathewson, T. K., Puruandiro, Mexico
Melvin, D. N., Linoleumville, N. Y.
Merriman, Mansfield, Bethlehem, Pa.
Meyer, R.....Monterey, Mexico
Moler, W. G......Mexico City
Myers, William M., Puebla, Mexico

Nauman, George, Philadelphia, Pa.
Northrop, Albert A., Brown Station, N. Y.

Ortiz, Eduardo.....Mexico City

Peimbert, A.......Mexico City
Pew, Arthur.......Atlanta, Ga.
Polk, W. Anderson, New York City
Potter, H. W..Torreon, Mexico
Puga, Guillermo Beltran y, Mexico City

Richardson, J. H., New York City
Ridgway, Robert, Poughkeepsie, N. Y.
Russell, S. Bent..St. Louis, Mo.
Ryder, Ely M. T., New Haven, Conn.

Selmer, J. K......Mexico City
Sherrerd, M. R...Newark, N. J.
Smith, G. E. P...Tucson, Ariz.
Smith, J. Waldo..New York City
Smith, James, Coatzacoalcos, Mexico
Stacpoole, S. W., Orizaba, Mexico
Stuart, J. T..Philadelphia, Pa.
Sundstrom, A. Y...Mexico City

Tribus, Louis L..New York City
Turner, N...Monterey, Mexico

Williams, G. S., Ann Arbor, Mich.

There was also present a large number of ladies of the families of members, and many Mexican engineers, members of the Mexican Association of Engineers and Architects, of the Association of the Military College, and of the Sociedad "Antonio Alzate."

In addition to this, Special Delegates to the Convention were sent by the Governors of Yucatan, Puebla, and Vera Cruz.

It is impossible to state the total attendance at this Convention accurately, but it is estimated that the total number participating in the various meetings and excursions was not far from 500.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, September 4th, 1907.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper entitled "Comparison of Rainfall and Run-Off in the Northeastern United States," by John C. Hoyt, Assoc. M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for May, 1907.

Wednesday, September 18th, 1907.—8.30 P.M.—At this meeting a paper entitled "A Description of the Recently Installed Sewage Disposal Works for the Village of Ballston Spa, New York," by G. L. Robinson, Assoc. M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for May, 1907.

Wednesday, October 2d, 1907.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and two papers will be presented for discussion, as follows: "Reinforced Concrete Towers," by D. W. Krellwitz, Jun. Am. Soc. C. E.; and "Reinforced Concrete Pipe for Carrying Water Under Pressure," by Chester Wason Smith, Assoc. M. Am. Soc. C. E.

These papers are printed in this number of *Proceedings*.

Wednesday, October 16th, 1907.—8.30 P. M.—At this meeting a paper entitled "The Bracing of Trenches and Tunnels, With Practical Formulas for Earth Pressures," by J. C. Meem, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Society of Engineers, 17 Victoria Street, Westminster, S. W., England.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Civil Engineers' Club of Cleveland, 718 Caxton Building, Cleveland, Ohio.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa.

Engineers' Society of Western Pennsylvania, 803 Fulton Building, Pittsburg, Pa.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

Louisiana Engineering Society, 604 Tulane-Newcomb Building, New Orleans, La.

Engineers' Club of Central Pennsylvania, Corner Second and Walnut Streets, Harrisburg, Pa.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Teknisk Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Société des Ingénieurs Civils de France, 19 Rue Blanche, Paris, France.

Svenska Teknologföreningen, Brunkebergstorg 18, Stockholm, Sweden.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Pacific Northwest Society of Engineers, 617–618 Pioneer Building, Seattle, Wash.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Memphis Engineering Society, Memphis, Tenn.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

The Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Cleveland Institute of Engineers, Middlesbrough, England.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Rochester Engineering Society, Rochester, N. Y.

Brooklyn Engineers' Club, 197 Montague Street, Brooklyn, N. Y.

Montana Society of Engineers, Butte, Montana.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendix* to the Annual Report of the Board of Direction for the year ending December 31st, 1906, contains a summary of all searches made to that date.

* *Proceedings*, Vol. XXXIII, p. 20 (January, 1907).

ACCESSIONS TO THE LIBRARY.

From May 7th to August 7th, 1907.

DONATIONS.*

SETTING OUT OF TUBE RAILWAYS.

By G. M. Halden. Cloth, 11 x 8½ in., illus., 68 pp. London, E. & F. N. Spon, Ltd.; New York, Spon & Chamberlain, 1907. $4.00.

The contents of this book appeared originally as a series of articles in *The Engineer*. Practical details on the setting out and construction of tube railways, which have been confirmed by actual experience by the author, only are described, all matter not bearing distinctly on the subject being omitted. The author assumes a knowledge of trigonometry and the use of the theodolite on the part of the reader. The Contents are: Preliminary Survey of Tube Railways; Instruments and Setting Out Appliances; Adjustment of Instruments; Levelling; Setting Out at Poole Street Shaft; Fixing Reels for Heavy Bobs; Starting Shield on Twenty-Chain Curve; Setting Out Tunnels with Wire Stretched in Bottom of Heading; Description of Seventeen-Chain Curve; Traverse I, from Poole Street to Old Street; Traverse II, from Essex Road to Drayton Park; Permanent Way; Blackwall Tunnel under Compressed Air; Sounding the River on Site of Tunnel; London County Council Sewer Tunnel; Traverse V, from Elliott Place to Van Brugh Park; Traverse VI from Van Brugh Park to Siebert Road; Page of Don'ts. There is an index of two pages.

THE MECHANICS OF HOISTING MACHINERY.

Including Accumulators, Excavators, and Pile-Drivers. Text-Book for Technical Schools and a Guide for Practical Engineers. By Dr. Julius Weisbach and Professor Gustav Herrmann. Authorized Translation from the Second German Edition, by Karl P. Dahlstrom. Cloth, 9 x 6 in., illus., 8 + 332 pp. New York, The Macmillan Company; London, Macmillan & Co., Ltd., 1907. $3.00 net.

Several volumes of Weisbach's work on Engineering Mechanics have been made familiar to English readers through the translations of Messrs. Coxe, DuBois and Klein. The present volume is translated from Professor Herrman's revised edition of Weisbach's work, and has never before been published in the English language. The book, as stated on the title-page, is intended as a text-book for students in the more advanced courses in the mechanics of machinery, and as a guide to practical engineers. References, in the text, to previous volumes of Weisbach's Mechanics, are to the English translations, unless otherwise specified. Both metric and English measurements are given, the latter being enclosed in brackets. The Contents are: Levers and Jacks; Tackle and Differential Blocks; Windlasses, Winches, and Lifts; Hydraulic Hoists, Accumulators, and Pneumatic Hoists; Hoisting Machinery for Mines; Cranes and Sheers; Excavators and Dredges; Pile-Drivers. There is an index of two pages.

THE CHEMISTRY AND TECHNOLOGY OF MIXED PAINTS.

By Maximilian Toch, Assoc. Am. Soc. C. E. Cloth, 9½ x 6 in., illus., 16 + 166 pp. New York, D. Van Nostrand Company, 1907. $3.00 net. (Donated by the Author.)

This book is intended as a reference work, on the science and technology of modern paints, for the student in chemistry, the engineer, the paint manufacturer and paint chemist, all of whom are supposed by the author to have had previous knowledge or training in the subject. Some of the subject-matter has been extracted from lectures delivered by the author at various universities and before scientific bodies, but most of it is here published for the first time. The first nine chapters are devoted to a discussion of the machinery necessary in the manufacture of mixed paints and the raw materials most generally used in such manufacture. Under the chapters on Pigments the author has omitted all mention of such as are rarely used, or gone out of use He also advocates the

*Unless otherwise specified, books in this list have been donated by the publisher.

proper labelling as to the constituents of mixed paints by manufacturers. There is a chapter on the chemical technology of linseed oil, followed by chapters on the manufacture of various driers used for paint purposes. Combining mediums and water in the composition of mixed paints is next discussed, followed by chapters on special paints for floors, etc., and on the analysis of mixed paints. There is an appendix containing a translation of a Consular report on the Chinese oil tree. The Contents are: The Manufacture of Mixed Paints; The Pigments; Yellow, Blue and Green Pigments; The Inert Fillers and Extenders; Paint Vehicles; Special Paints; Analytical; Consular Reports on China Wood Oil. There is an Index of four pages.

THE DESIGN OF WALLS, BINS AND GRAIN ELEVATORS.

By Milo S. Ketchum, Assoc. M. Am. Soc. C. E. Cloth, 9 x 6½ in., illus., 16 + 393 pp. New York, The Engineering News Publishing Co.; London, Archibald Constable & Company, 1907. $4.00 net. (Donated by the Author.)

A presentation of a systematic analysis of the stresses due to granular materials, together with a discussion of the principles of design and the details of structures for holding such materials, has been the object of this book, according to the author. The first part of the book is devoted to the design of retaining walls, a knowledge of the theory of retaining walls being necessary to an understanding of the theory of pressure in bins. The design of bins for coal, ore, etc., is taken up and studied in the second part of the book, followed by a discussion of the design of grain bins and elevators. Graphic methods have been used for calculating the pressures on retaining walls and in hopper bins, as well as algebraic methods for calculating stresses. The theory of reinforced concrete, now used extensively in the construction of retaining walls, bins, and grain elevators, is discussed, and formulas necessary for use in the design of such structures are developed. All the available experiments on the pressure of granular materials have been included by the author. The subject of costs has been thoroughly considered, and examples of actual construction are given in detail. The Contents are: Part I, The Design of Retaining Walls; Rankine's Theory; Coulomb's Theory; Design of Masonry Retaining Walls, Reinforced Concrete Retaining Walls; Experiments on Retaining Walls; Examples of Retaining Walls; Cost of Retaining Walls. Part II, The Design of Coal Bins, Ore Bins, etc.; Types of Coal Bins, Ore Bins, etc.; Stresses in Bins; Experiments on Pressures on Bin Walls; The Design of Bins; Examples and Details of Bins; Cost of Bins; Methods of Handling Materials. Part III, The Design of Grain Bins and Elevators; Types of Grain Elevators; Stresses in Grain Bins; Experiments on the Pressure of Grains in Deep Bins; The Design of Grain Bins and Elevators; Examples of Grain Elevators; Cost of Grain Bins and Elevators. There are two Appendices and an Index of five pages.

PRACTICAL ILLUMINATION.

By James Raley Cravath and Van Rensselaer Lansingh. Cloth, 9½ x 6 in., illus., 7 + 356 pp. New York, McGraw Publishing Company, 1907. $3.00 net.

In these pages no attempt has been made to treat of the apparatus for the production of light, specific data and suggestions of how best to use the light for interior illumination only being given. In Part I the effects produced by various deflectors, shades and globes are discussed, together with the effects on the eye by different arrangements of artificial lighting. A number of tests of the light-distribution of various illuminants, with different reflectors and shades are also given. Almost all these tests were made at the Electrical Testing Laboratories of New York City, no tests made by manufacturers being given. In the Appendix are given many of the manufacturers' names and numbers, or trade designations, of the reflectors, shades and globes tested. Part II is devoted to practical examples of rooms of various kinds with both good and bad lighting arrangements, the desirable and undesirable features of every case being fully discussed. The Contents are: Introduction; The Laws and Measurement of Light; Light and the Eye; Calculation of Illumination; Individual Incandescent Electric Lamps and Their Reflectors, Shades and Globes; Individual Gas Burners and Their Reflectors, Shades and Globes; Acetylene Gas Burners and Their Shades; Incandescent Electric Lamp Clusters and Bowls; Nernst Lamps and Their Globes; Electric Arc Lamps; Gas Arc Lamps; Vapor Lamps; Demonstration Room Tests; Comparison of Illuminants; Introduction to Practical Examples; Residence Lighting; Desk, Drafting Room and Office Lighting; The Lighting of Public Halls and Lodge Rooms; The Lighting of Large Dining and Banquet Rooms; The Lighting of Large Public Rooms, Depots, Lobbies, etc.; The Lighting of

Halls and Corridors of Large Office Buildings; The Lighting of Theaters; The Lighting of Churches; The Lighting of Libraries, Reading and School Rooms; Car Lighting; Store Lighting; Show Window Lighting; Shop and Factory Lighting; Miscellaneous Examples of Lighting; Appendix. There is an index of eight pages.

THE ENGINEERING INDEX ANNUAL FOR 1906.

Compiled from the Engineering Index Published Monthly in *The Engineering Magazine* during 1906. Cloth, 9½ x 6½ in., 14 + 395 pp. New York and London, The Engineering Magazine, 1907. $2.00.

This volume is a continuation of the work edited and published, in 1884, by The Association of Engineering Societies, under the direction of the late J. B. Johnson, M. Am. Soc. C. E. The first index was followed by others in 1892, 1896, 1902 and 1906, respectively. As much of the literature of modern engineering becomes obsolete in five years, the time required to edit, and publish the previous volumes, it has been decided to continue the publication as an annual. The contents of the earlier indexes were arranged alphabetically by subject. This volume, however, following the arrangement of the engineering index published monthly by *The Engineering Magazine*, is classified under the several divisions of engineering practice—Civil, Electrical, Marine and Naval, Mechanical, Mining, and Railway Engineering. These main divisions are divided into the special classes which come under them, these entries being arranged alphabetically. Under each entry a brief abstract, showing the scope and purport of the article, is given. Serials are indexed under the first instalment only, except in case of short articles. This index has been brought down to the end of 1906, but a monthly continuation of it may be found in the issues of *The Engineering Magazine*.

HYDROMETALLURGY OF SILVER.

With Special Reference to Chloridizing Roasting of Silver Ores and the Extraction of Silver by Hyposulphite and Cyanide Solutions. By Ottokar Hofmann. Cloth, 9 x 6 in., illus., 10 + 345 pp. New York and London, Hill Publishing Company, 1907. $4.00.

In his treatment of this subject, the author has divided the book into two parts. The first part relates to the "Chloridizing Roasting of Silver Ores." This is stated to be the most important metallurgical operation in the hydrometallurgy of silver, the subsequent extraction of the silver by the solvent depending entirely on the quality of the roasting. Under this general heading the author takes up and discusses the Theory of Chloridizing Roasting; Crushing of the Ore; Percentage of Salt Required; Loss of Silver by Volatilization; Methods of Roasting; Consumption of Fuel; Reverberatory Furnaces Worked by Hand; Mechanical Roasting Furnaces; Collecting the Flue-Dust; Sulphating Roasting; Chloridizing of Argentiferous Zinc-Lead Ore; Chloridizing of Calcareous Ores. Part II relates to the "Extraction of the Silver" from the roasted ore by different solvents. After a short description of the process, the author discusses the different operations and appliances used, and which he himself has successfully practised in Mexico and the western part of the United States. The chapter headings under this part are: Lixiviation with Sodium Hyposulphite; Precipitation of Silver; Treatment of the Precipitate; Construction of Troughs; Trough Lixiviation; The Russell and Kiss Processes; The Augustin Process; Extraction with Sulphuric Acid; The Ziervogel Process; Treatment of Silver Ores Rich in Gold. In the last chapter, the Cyanidation of Auriferous Silver Ores is discussed. There is an index of sixteen pages.

RAILWAY PROBLEMS.

Edited, with an Introduction. By William Z. Ripley. Cloth, 9 x 6 in., illus., 32 + 686 pp. Boston, Ginn & Company, 1907. $2.25.

This volume is composed of reprints of articles on railway economics, collected from various books and technical journals. The editor, in the preface, states that its purpose is two-fold: "to render more easily accessible to the interested public, valuable technical material upon a question of paramount interest

and importance at the present time," and "to facilitate the work of the college instructor in the economics of transportation." Some of the articles are merely for reference reading, but others, especially the decisions of the Interstate Commerce Commission, provide material which may be debated and discussed in the class room. As economic facts only are discussed by the editor, many of the reprints of the above-named decisions have been stripped of the legal material, which has simplified them for the use of students. It is stated that the book is intended to be used in connection with some standard treatise upon the economics of transportation, in the conduct of courses. The Contents are: A Chapter of Erie (Early speculative and financial scandals); by Hon. Charles Francis Adams. Standard Oil Rebates; by Ida M. Tarbell. The Building and Cost of the Union Pacific (Construction companies); by Henry Kirke White. The Southern Railway & Steamship Association (A typical pool); by Henry Hudson. The Theory of Railway Rates; by Frank W. Taussig. Unreasonable Rates: The Cincinnati Freight Bureau Case; The Maximum Freight Rate Decision; The Savannah Naval Stores Case. Relative Rates: The Hutchinson, Kan., Salt Case; The Eau Claire, Wis., Lumber Case; The Chattanooga Case. The Long and Short Haul Clause: The St. Cloud, Minn., Case; The Savannah Fertilizer Case. The Trunk Line Rate System; by William Z. Ripley. The Southern Basing Point System: The Troy, Ala., Case. The Alabama Midland Decision; The Dawson, Ga., Case. The Southern Rate System: The Danville, Va., Case. Transcontinental Freight Rates: The St. Louis Business Men's League Case. Export and Domestic Rates (Atlantic & Gulf competition). Freight Classification: The Hatters' Furs Case. Economic Waste in Transportation; by William Z. Ripley. The Northern Securities Company (Railroad consolidation); by Balthasar H. Meyer. The Interstate Commerce Law as Amended in 1906; by Frank H. Dixon. Reasonable Rates (Judicial determination); by Alton D. Adams. The Doctrine of Judicial Review; by H. S. Smalley. The English Railway and Canal Commission of 1888; by S. J. McLean. Railway Regulation in France; by W. H. Buckler. Railroad Ownership in Germany; by Balthasar H. Meyer. There is an index of four pages.

PORTS MARITIMES.

Par De Cordemoy. Tome I. Leather, 7 x 5 in., illus., 8 + 576 pp. Paris, H. Dunod et E. Pinat, 1907. 15 francs.

In this first volume, the author treats of the sea, the winds, the waves, etc., the physical side of the subject, and it is stated that this work may be recommended for its practical character, the numerous examples given to support the author's descriptions, and the clearness and exactness of its illustrations. The second volume will treat of the methods of constructing jetties, quays, dikes, the utilization of harbors, etc. The Contents are: Mer; Vents; Ondes Liquides; Vagues; Marées; Les Marées dans les Fleuves; Courants; Côtes; Barres et Deltas; Dragages; Protection des Côtes; Généralités sur les Ports; Etudes d'un Etablissement Maritime; Ports; Ports a Chasses Naturelles; Ports a Moles Convergents; Ports sur Plages de Sable; Ports a Jetées; Fleuves et Estuaires; Matériaux Employés à la Mer; Phares; Bouées; Notions de Cosmographie; Notions de Trigonométrie Sphérique; Notions de Navigation; Hydrographie; Navires.

WATER-WORKS MANAGEMENT AND MAINTENANCE.

By Winfred D. Hubbard, Assoc. M. Am. Soc. C. E., and Wynkoop Kiersted, M. Am. Soc. C. E. Cloth, 9 x 6 in., illus., 6 + 429 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907. $4.00.

It is stated that the questions relating to the maintenance and operation of a system of water-works often depend, for their proper solution, upon the details of the original design. The authors, therefore, have outlined, in Part I of their book, the various methods of securing a water supply. Part II deals with matters connected with the routine management of a water-works plant. The questions arising in the dealings of municipalities with private water companies are discussed in Part III, and the principles involved in the fixing of water rates and the valuation of water-works property are presented in detail. The Chapter Headings are: Ground-Water Supply; River-Water Supply; Pumping Engines; Impounded Supplies; Plans and Records; Extensions; Service Connections; Meters; Care of Appurtenances; Alterations and Repairs; Maintenance of Quality; Water Waste; Electrolysis; Fire Protection; Accounts; Financial Management; Rules and Regulations; Annual Reports; Franchise, Water Rates, Depreciation. There is an index of eight pages.

CONCRETE-STEEL BUILDINGS.

By W. Noble Twelvetrees. Cloth, 7½ x 5 in., illus., 12 + 408 pp. London, Whittaker & Co., 1907. $3.25 net. (Presented by The Macmillan Co.).

In a previous work, "Concrete-Steel," the author discussed the theory and practice of concrete construction. In this volume he presents detailed particulars of buildings designed for use in Great Britain, on the Continent, and in America, as dock sheds, railway goods stations, locomotive sheds, warehouses, manufactories, workshops, flour mills and granaries, hospitals, hotels, residences, churches, theatres, and public halls. In order to emphasize the necessity for correct design, competent supervision and skillful construction, the last chapter is devoted to descriptions of some failures in concrete-steel construction. An Appendix is added, which contains classified lists of concrete-steel structures erected in the United Kingdom. The Index contains references to details of the buildings described, to data concerning the proportions and consistency of the concrete used, the amount of reinforcement and the strength of materials, the results of tests, contractors' plant, and methods of practical construction.

HOW TO DESIGN A GAS ENGINE.

With Full Working Drawings for a 7 B. H. P. Gas Engine. By Horace Allen. Cloth, 10 x 7½ in., illus., 30 + 1 pp. Manchester, England, The Scientific Publishing Co. 2 shillings 6 pence.

This small volume consists of a description, together with a series of working drawings, of a 7 b. h. p. gas engine of the ordinary single-acting Otto type. The fuel used in this engine is an average quality of ordinary illuminating gas. The chapter headings are: Crank Shaft; Connecting Rod; Cylinder; Water Jacket; Cylinder Liner; The Piston; The Flywheel; Operation of Main Valves; Valve Seats, Valves, and Operating Mechanism; Governors; Spiral or Skew Gear. There is a one-page index.

STRESSES IN STRUCTURES.

And the Accompanying Deformations. By A. H. Heller. Cloth, 9 x 6 in., illus., 324 pp. Columbus, Ohio, 1907. $4.00. (Presented by A. G. Geren, Agent, Eugene Dietzgen Company.)

The manuscript of this work was used by Professor Heller in his classes at the Ohio State University. It is intended both as a reference book for the profession and as a textbook for schools. The book, as it is here presented, covers stresses in all forms of simple trusses; but it is stated that it was the intention of the author, had he lived to finish the work, to cover also the common forms of statically indeterminate structures as well as the three-hinged arch and cantilever bridges, as shown by frequent references to chapters which are not included in the book. The Contents are: Stresses and Deformations Within the Elastic Limit; Stresses and Deformations Beyond the Elastic Limit; The Laws of Equilibrium and Their Application; Application of the Laws of Equilibrium to the Structures as a Whole; Reactions; Application of the Laws of Equilibrium to any one Joint; Application of the Laws of Equilibrium to a Part of a Structure; Stresses in Beams and Girders; Deflection of Beams and Girders; Special Cases of Beams and Girders Loaded and Supported in Different Ways; Stresses in Blocks and Columns; Types of Trusses; Stresses in Simple Bridge Trusses for Uniform Loads; Stresses in Railway Bridges from Wheel Loads; Stresses in Bridges from Horizontal Forces. There is an index of fourteen pages.

AMERICAN ELECTRIC RAILWAY PRACTICE.

By Albert B. Herrick and Edward C. Boynton. Cloth, 9½ x 6½ in., illus., 5 + 403 pp. New York, McGraw Publishing Company, 1907. $3.00 net.

Practical information relating to the construction, operation, and maintenance of the present-day American electric railway is to be found in this volume. Some of the subject-matter has already appeared in the *Street Railway Journal*, but the remainder has been gathered from the personal experiences of the authors in the various departments of the steam and electric railway transportation business. It is stated that the up-to-date methods of conducting the work

of the different departments of many of the most advanced roads are explained and illustrated, together with the apparatus used by such roads. All methods that have become obsolete have been omitted. The object has been not to advocate certain methods of management, etc., but rather to describe such as have been adopted with success in different localities. The book also includes many of the modern methods used in steam railway operation. The chapter headings are: Preliminary Estimates; Field Engineering for Interurban Roads; Railway Track Construction; Location of Power Station; Overhead Circuit, Time Tables and Schedules; Train Despatching and Signals; Rolling Stock; The Design of a Modern Car House; The General Design of a Modern Repair Shop; Maintenance of Interurban Track; Overhead Line Maintenance; The Operation of the Main Repair Shop; Maintenance of Equipment; Miscellaneous Subjects. There is an index of five pages.

SPECIFICATIONS FOR STREET ROADWAY PAVEMENTS.

By S. Whinery, M. Am. Soc. C. E. Paper, 9 x 6 in., 56 pp. New York, The Engineering News Publishing Company, 1907. 50 cents net.

This set of specifications for standard street pavements, embodying as it does the latest approved practice, is offered by the author to city engineers and municipal authorities as an aid in preparing specifications for any particular project. In order to make the specifications more useful numerous foot notes have been added, which refer to alternative requirements and methods of construction, and give reasons for the preference and adoption of the construction called for in the specification. No attempt has been made to submit specifications for proprietary or patented pavements, or for those composed wholly or in part of materials which are patented or protected by trademarks. A proposed form for a general specification for experimental or untried pavements will be found at the end of the pamphlet. The author states that he has aimed to make these specifications fair and just to the contractor, and that he has included many details which, from his own experience, he has found essential to the production of high-class work. The Contents are: Introductory; General Description and Provisions; Foundations; Concrete, Old Paving Stone, Broken Stone; Bituminous Pavements; Asphalt; Rock Asphalt, Block Asphalt; Granite, Brick and Wood-Block Pavements; General, Relating to All Pavements; Payments; Specifications for Experimental or Untried Pavements.

ELECTRIC LIGHT WIRING.

By C. E. Knox. Cloth, 9½ x 6 in., illus., 5 + 219 pp. New York, McGraw Publishing Company, 1907. $2.00 net.

The subject of electric light wiring has been treated by the author in such a manner as to make it intelligible to persons having only a general knowledge of electricity without omitting any of the technical accuracy. It is stated that this volume is not a reprint of the National Electric Code, nor an amplification of the same, but that it contains data and information used by the author in his own practice, the greater portion of such data never having been published. Numerous practical examples are given in order to illustrate more clearly the methods of designing electric wiring equipments. Sizes of lined and unlined conduits required for various-sized conductors are shown in Figs. 93 to 119 in the Appendix. The Contents are: Systems of Wiring; Methods of Wiring; Conductors; Fuses and Safety Devices; Cut-Out Panels and Cabinets; Outlet Boxes, Outlet Insulators, etc.; Feeders and Mains; Testing of Insulation Resistance, etc.; Wire Calculations; Alternating-Current Wiring; Calculation of Alternating-Current Circuits; Examples; Overhead Line Work; Underground Line Work; Appendix.

RAILWAY ORGANIZATION AND WORKING.

A Series of Lectures Delivered Before the Railway Classes of the University of Chicago. Edited by Ernest Ritson Dewsnup. Cloth, 8 x 5 in., illus., 11 + 498 pp. Chicago, The University of Chicago Press, 1906. $2.00 net.

During the past two years the University of Chicago, in co-operation with a number of railway officials, has conducted courses bearing upon the traffic, auditing, operating and other questions of railway organization. This volume

is a compilation of the special lectures delivered before these classes by prominent men connected with the various railways, each of whom describes and discusses the work of his own particular department in a practical and non-technical manner. The Contents include chapters on "The Work of the Law Department of a Railroad Company," by Blewett Lee, General Attorney, Illinois Central Railroad; "The Passenger Department," by Percy S. Eustis, Passenger Traffic Manager, Chicago, Burlington & Quincy Railroad; "Railroad Advertising," by Charles S. Young, in Charge of Advertising, Chicago, Milwaukee & St. Paul Railway, etc. In the Appendix a few papers by students are given, which are descriptive of points connected with the freight service. There is an index of seven pages.

THE BACTERIOLOGICAL EXAMINATION OF WATER SUPPLIES.

By William G. Savage. Cloth, 8 x 5 in., illus., 16 + 297 pp. Philadelphia, P. Blakiston's Son & Co., 1906. $2.50 net.

The bacteriological examination of water is stated to be the most valuable of all available methods by which to judge of the purity of a water supply. It has been the author's intention, in this book, to demonstrate only the established facts as to this particular method of water purification, and to bring the varied data, upon which it is based, into ordered relationship. He has, therefore, treated the subject from a critical standpoint, and has drawn only those practical conclusions which seem justified by the available evidence. The results of some of the investigations embodied in the book have appeared in various scientific journals, but many are new. There is an appendix in which a summary of procedure is recommended for the bacteriological examination of a sample of water. This is said to be liable to modification according to the water-supply examined, but is suited to most cases. There is also a lengthy bibliography of recent articles and books on the subject. The Chapter headings are: Influences Affecting Bacteria in Water; The Quantitative Bacterial Content of Natural Waters; Bacteriology of Excreta and Sewage in Relation to the Bacteriological Examination of Water; Soil in Relation to the Bacteriological Examination of Water; *Bacillus Coli* and Allied Organisms; The Eberth or Typhoid Group; Other Intestinal Bacteria; The Content of Various Waters with Regard to the Presence of *B. Coli*, *B. Enteritidis Sporogenes*, and Streptococci; Bacterial Indicators of Pollution; Interpretation of Results in the Bacteriological Examination of Water; Classification of Bacteria Found in Water; Collection and Transmission of Samples; General Quantitative Examination; Methods for the Enumeration and Identification of *B. Coli* and Allied Organisms; The Examination of Water for the Typhoid Bacillus; The Examination of Water for Other Intestinal Organisms. There is an index of five pages.

THE PREVENTION OF ACCIDENTS.

By F. W. Johnson. Ed. 2. Paper, 8½ x 6 in., 37 pp. New York, McGraw Publishing Company, 1907. 25 cents net.

This pamphlet consists of suggestions to the employees of street railway companies generally, concerning practical means of preventing the more common classes of accidents and as to the proper handling of such accidents when they do occur. There are short discussions of the following topics: The Accident; The Accident Report; Witnesses to Accidents; Courteous Treatment; The Prevention of Accidents; Rear-End Collisions of Cars; Collisions with Teams; etc.

THE ELEMENTS OF MECHANICS.

By W. S. Franklin and Barry Macnutt. Cloth, 9 x 6 in., illus., 11 + 283 pp. New York, The Macmillan Company, 1907. $1.50 net.

In a secondary title, the authors state that this book is intended for use as a textbook for colleges and technical schools. The first three chapters are devoted to introductory matter which the authors consider essential to the study of the chapters which follow. The remaining chapters are discussions on elementary mechanics, with a final chapter on Wave Motion and Oscillatory Motion. There are numerous explanatory notes scattered through the text, and at the end of each chapter there are problems to be worked out by the student. The Contents are: Introduction; The Measurement of Length, Angle, Mass and Time; Physical Arithmetic; Simple Statics; Translatory Motion; Friction, Work and Energy; Rotatory Motion; Elasticity (Statics); Hydrostatics; Hydraulics; Wave Motion and Oscillatory Motion. There is an index of five pages.

AMERICAN STREET RAILWAY INVESTMENTS, 1907.

Published Annually by the Publishers of the *Street Railway Journal,* for the Use of Bankers, Brokers, Capitalists, Investors, and Street and Interurban Railway Companies. Cloth, 13 x 10 in., illus., 54 + 453 pp. New York, The McGraw Publishing Company, 1907. $5.00.

This publication, of which this volume is the fourteenth annual edition, is issued in connection with the *Street Railway Journal.* It contains 453 pages of statistical matter, an increase of 21 pages over the edition of 1906. It covers the street railway companies in the United States, Canada, West Indies, Hawaii and the Philippine Islands. The names of the companies are arranged alphabetically under State and city, a short history of each road being given, with its capital stock, funded debt, plant, and the names and addresses of its officers, together with those of the general offices, power stations and repair shops. At the end of each report the date on which such information was obtained is given. There are 44 maps in the volume, on which the systems of 47 separate companies are shown, and an index to the street railway companies is also included.

ALLOWABLE PRESSURES ON DEEP FOUNDATIONS.

By Elmer Lawrence Corthell, M. Am. Soc. C. E. Cloth, 9 x 6 in., illus., 98 pp. New York, John Wiley & Sons, 1907. $1.25 net.

In 1902 the Argentine Government appointed a Board—of which the author was Chairman—to examine and report upon propositions for the construction of a port at the City of Rozario, on the Paraná River. A discussion of the question of the allowable pressure upon the material composing the bed of the river disclosed such a wide difference of opinion among the experts that the author decided to make a thorough investigation of the subject. The work was put into the hands of Charles R. Wyckoff, Jr., Jun. Am. Soc. C. E., and a circular letter was addressed to engineers in various countries, asking for information and data, either from their own, or from the experiences of others, in such work. The results were presented first in the form of a paper read before the Institution of Civil Engineers, and this volume is an elaboration of the paper. Only thirty replies of any value were received in answer to the circular letters sent out, but the tables in Appendix A give data of 178 examples of pressure on foundations. These tables are subdivided so that a short description is given of each example. Appendix B contains abstracts from reports upon pressures and friction. Appendices C and D are composed of personal statements and abstracts of published works, together with a bibliography of subject compiled by Mr. Wyckoff. A brief analysis of the tables is given by the author showing the safe pressures on various classes of materials such as fine sand, coarse sand and gravel, sand and clay, alluvium and silt, hard clay and hardpan.

BARRAGES EN MAÇONNERIE ET MURS DE RÉSERVOIRS.

Par Henri Bellet. Paper, 10 x 6 in., illus., 13 + 335 pp. Grenoble, A. Gratier & Jules Rey, 1907. 8 francs.

The author has divided his book into four parts. The first part is devoted to an elementary study of the subject, such as rules for calculating the thrust and normal pressures developed in dams of simple profile. Short descriptions of the principal methods of constructing dams, earth embankments, dams composed of several materials, of reinforced concrete, and of masonry are also given. The historical study of dams is taken up in the second part. The author shows the successive phases through which dam construction has passed, from the methods of M. de Sazilly to those of M. Maurice Lévy. The mathematical study of the subject is discussed in the third part. In the fourth part, the author describes a number of high dams constructed in France and other countries; together with new methods for the calculations for, and the construction of, modern dams. The appendices contain abstracts from the laws which govern the construction of dams in France, and these are followed by a short bibliography. The Contents are: Considérations Générales: Calculs Elémentaires de Stabilité; Divers Modes de Construction des Barrages. Etude Historique des Barrages: Barrages Anciens; Profils d'Egale Résistance de M. Delocre; Méthode de M. Bouvier; Etude de la Stabilité Suivant des Joints Obliques; Méthode de M. Maurice Levy; Barrages avec Puits. Théorie du Barrage: Etude des Actions Moléculaires Developpées dans un Barrage

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Public Baths and Wash-Houses. A Treatise on Their Planning, Design, Arrangement and Fitting, having Special Regard to the Acts Arranging for their Provision, with Chapters on Turkish, Russian and other Special Baths, Public Laundries, Engineering, Heating, Water Supply, etc. By Alfred W. S. Cross. London, B. T. Batsford, 1906.

L'Ozone et ses Applications Industrielles. Par H. de la Coux. Paris, Ch. Dunod, 1904.

Metallurgical Calculations. By Joseph W. Richards. Pt. II, Iron and Steel. New York, McGraw Publishing Company, 1907.

Engineering Work in Towns and Small Cities. By Ernest McCullough. Chicago, Technical Book Agency, 1906.

Les Grands Tunnels des Alps et du Jura. Par James Ladame. Paris, Dubuisson et Cie., 1889.

Report from the Select Committee on Rivers Pollution of Great Britain on the River Lea. Together with the Proceedings of the Committee, Minutes of Evidence, and Appendix. London, Messrs. Eyre and Spottiswoode, 1886.

Report of the Royal Commission of Great Britain on Metropolitan Sewage Discharge. 4 Vol. First Report, Second and Final Report, Minutes of Evidence taken before the Commission, from July, 1882, to October, 1884, together with a Selection from the Appendices and a Digest of the Evidence, Pts. I-II. London, Eyre and Spottiswoode, 1884-85.

Transactions of the Sanitary Institute of Great Britain. Vol. 3-18. London, Sanitary Institute, 1882-98.

Der Eisenbahnbau. Handbuch der Ingenieurwissenschaften. IV. Band. Erste Abteilung. Herausgegeben von F. Loewe und H. Zimmermann. Leipzig, Wilhelm Engelmann, 1907.

The Steam-Engine and Other Heat-Motors. By W. H. P. Creighton. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907.

Sewage and the Bacterial Purification of Sewage. By Samuel Rideal. Third Edition. London, The Sanitary Publishing Co., Ltd.; New York, John Wiley & Sons, 1906.

Locomotives: Simple, Compound and Electric. By H. C. Reagan. Fifth Edition, Revised and Enlarged, New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907.

Brooklyn Daily Eagle Almanac, 1907. Brooklyn, Brooklyn Daily Eagle.

Electric Railway Engineering. By H. F. Parshall and H. M. Hobart. New York, D. Van Nostrand Company, 1907.

Mine Timbering. By Wilbur E. Sanders, Bernard MacDonald, Norman W. Parlee and others. New York and London, Hill Publishing Company, 1907.

The Principles of Copper Smelting. By Edward Dyer Peters. New York and London, Hill Publishing Company, 1907.

The Common Bacterial Infections of the Digestive Tract and the Intoxications Arising from Them. By C. A. Herter. New York, The Macmillan Company; London, Macmillan & Co., Ltd., 1907.

Moody's Manual of Railroads and Corporation Securities, 1907. New York, The Moody Corporation; London, Fredc. C. Matheson & Sons; Amsterdam, J. H. De Bussy.

A Treatise on the Mathematical Theory of Elasticity. By A. E. H. Love. Second Edition. New York, G. E. Stechert & Co.; Cambridge, University Press, 1906.

The Fire at the Iroquois Theatre, Chicago, 30th December, 1903. London, The British Fire Prevention Committee, 1904.

Der Talsperrenbau in Deutschland. Von Sympher. Internationaler Ständiger Verband der Schiffahrts-Kongresse. Berlin, Wilhelm Ernst u. Sohn, 1907.

Port of Para, Brazil. By Elmer L. Corthell, M. Am. Soc. C. E. Permanent International Assoc. of Navigation Congresses. Brussels, Printing Office of the Public Works (Co. Ltd.), 1907.

List of Members, 1907, Permanent International Assoc. of Navigation Congresses. Brussels, Imprimerie des Travaux Publics (Société Anonyme), 1907.

Report of Proceedings, Xth. International Navigation Congress, Milan, 1905. Milan, Organizing Committee of the Congress, Secretarial Department, 1906.

The Mineral Industry: Its Statistics, Technology and Trade During 1906. Vol. 15. Edited by W. R. Ingalls. New York, Hill Publishing Co., 1907.

Zoölogie Appliquée en France et aux Colonies. Par Jacques Pellegrin. Bibliothèque du Conducteur de Travaux Publics. Paris, H. Dunod et E. Pinat, 1907.

SUMMARY OF ACCESSIONS.

From May 7th to August 7th, 1907.

Donations (including 120 duplicates)	736
By purchase	46
Total	782

MEMBERSHIP.

ADDITIONS.

(May 8th to August 9th, 1907.)

MEMBERS.		Date of Membership.
BOWER, CHARLES PHILLIP. Engr., E. E. Smith Contr. Co., 709 Arcade Bldg., Philadelphia, Pa.		June 5, 1907
BRADLEY, FRANK EDWARD. City Engr., New Rochelle, N. Y.		Feb. 6, 1907
BRIGGS, WALDO CLAYTON. Care, Degnon Contr. Co., 60 Wall St., New York City		July 10, 1907
CHASE, MARVIN. Secy., Wenatchee Canal Co., Wenatchee, Wash.		June 5, 1907
CODE, WILLIAM HENRY. Chf. Engr., U. S. Indian Service, 522 Bumiller Bldg., Los Angeles, Cal.		June 5, 1907
COLLIER, BYRAN CHEVES. Asst. Engr., Bureau of Highways, Bronx, 2721 Bainbridge Ave., Bronx, New York City	Assoc. M. M.	Oct. 3, 1900 June 4, 1907
CORNER, CHARLES. Res. Engr., Rhodesia Rys. (Northern Extensions), Box 422, Bulawayo, Rhodesia, South Africa	Assoc. M. M.	May 1, 1895 Mar. 5, 1907
CROSBY, WALTER WILSON. Johns Hopkins Univ., Baltimore, Md.		July 10, 1907
DAGGETT, HERBERT CHAPIN. 176 Federal St., Boston, Mass.		July 10, 1907
DEVELIN, RICHARD GRIFFITH. Room 360, Broad St. Station, Philadelphia, Pa.		May 1, 1907
DIMMICK, JOHN BAGLEY. U. S. Asst. Engr., 321 Lehigh Ave., Pittsburg, Pa.		July 10, 1907
EVANS, EDWIN GEORGE. Hampton, N. B., Canada		July 10, 1907
FAUNTLEROY, JAMES DEARING. Laguna Dam, Yuma, Ariz.		June 5, 1907
GAUT, ROBERT EUGENE. Engr. of Bridges, Ill. Cent. R. R., 6415 Minerva Ave., Chicago, Ill.		April 3, 1907
GIFFORD, ROBERT LADD. Pres., Illinois Eng. Co., 1210 Manhattan Bldg., Chicago, Ill.	Assoc. M. M.	May 6, 1903 June 4, 1907
GROSSART, LEWIS JOHN HENRY. 423 Commonwealth Bldg., Allentown, Pa.		May 1, 1907
HALL, JOHN LINCOLN. 78 Fifth Ave., New York City		July 10, 1907
HAMILTON, JOHN WILSON. 29 Broadway, New York City.		July 10, 1907
HARA AIYAR, NARAYANA PRANATARTI. Local Fund Engr., Anantapoor Dist., Madras Presidency, India		Dec. 5, 1906
HARPER, JOHN LYELL. Chf. Engr., Niagara Falls Hydr. Power & Mfg. Co., Niagara Falls, N. Y.		June 5, 1907
HEDGES, SAMUEL HAMILTON. 95 Yesler Way, Seattle, Wash.		July 10, 1907

MEMBERS (*Continued*).

Member		Date of Membership.
HELDT, HANS LUDWIG. Supt., The Sombrerete Min. Co., Sombrerete, Zac., Mexico		June 5, 1907
HILL, ERNEST ROWLAND. 10 Bridge St., New York City.		July 10, 1907
HOBBY, ARTHUR STANLEY. P. O. Box 886, Havana, Cuba	Assoc. M. M.	Sept. 4, 1901 June 4, 1907
HOWE, GEORGE EDWARD. Engr. in Chg. of Constr., Water Purification Works, Board of Public Service, Columbus, Ohio	Assoc. M. M.	Mar. 4, 1903 April 30, 1907
HUSS, GEORGE MOREHOUSE. Chf. Engr., Big Fork & International Falls Ry. Co., Big Falls, Minn		May 1, 1907
JERVEY, HENRY. U. S. Engr. Office, Mobile, Ala		June 5, 1907
JONES, ARTHUR LEWIS. Box 423, Ogden, Utah		July 10, 1907
KETCHUM, RICHARD BIRD. Chf. Engr., Independent Coal & Coke Co., Helper, Utah		June 5, 1907
KNOX, SAMUEL LIPPINCOTT GRISWOLD. 324 Prospect Ave., Milwaukee, Wis		July 10, 1907
LAYFIELD, ELWOOD NORMAN. Chf. Engr., Chic. Terminal Transfer R. R., 353 Grand Central Passenger Station, Chicago, Ill		June 5, 1907
LEGARÉ, BALIE PEYTON. Care, United Railroads of San Francisco, San Francisco, Cal		July 10, 1907
LEWIS, MARCUS WINFIELD. 300 West 4th St., Superior, Wis.		June 5, 1907
MACKAY, HENRY MARTYN. Associate Prof. of Civ. Eng., McGill Univ., Montreal, Que., Canada		July 10, 1907
MARROQUIN Y RIVERA, MANUEL. Chf. Engr., New Water Supply, Calle Sur 38, No. 214, City of Mexico, Mexico		June 5, 1907
MATHEWSON, THOMAS KNIGHT. Angamacutiro, Michoacan *via* Pénjamo, Mexico		May 1, 1907
MOGENSEN, PETER. 508 Columbia Bldg., Spokane, Wash.		July 10, 1907
MORITZ, CHARLES HOLLAND. Gen. Supt., Niagara Works of Aluminum Co. of America, Niagara Falls, N. Y	Assoc. M. M.	Oct. 2, 1901 April 2, 1907
MURTAUGH, MARK MAURICE. Cons., Hydr. and Constr. Engr., Kenyon Hotel, Salt Lake City, Utah		May 1, 1907
PUGA, GUILLERMO BELTRAN Y. Direccion de Obras Publicas, City of Mexico, D. F., Mexico		June 5, 1907
REIMER, WILLIAM HENRI VALE. 28 N. Maple Ave., East Orange, N. J		Mar. 6, 1907
SCHWITZER, JOHN EDWARD. Asst. Chf. Engr., Lines West of Port Arthur, Canadian Pac. Ry. Co., Winnipeg, Man., Canada		July 10, 1907
SHERRERD, JOHN MAXWELL. 122 North 2d St., Easton, Pa.		July 10, 1907

MEMBERS (*Continued*).

		Date of Membership.
SINKS, FRANK FORREST. Vice-Pres. and Secy., Condron & Sinks Co., 1442 The Monadnock, Chicago, Ill.	Assoc. M. M.	May 2, 1906 June 4, 1907
SLIFER, HIRAM JOSEPH. Room 1407, Wall St. Exchange Bldg., New York City		June 5, 1907
SNELL, THOMAS CULLEN BRYANT. 903 N. Y. Life Bldg., Minneapolis, Minn.		July 10, 1907
SPROUL, ARCHIBALD ALEXANDER. 142 Smith St., Peekskill, N. Y.		May 1, 1907
TABOR, ERNEST FREDERICK. Engr., U. S. Reclamation Service, Corbett, Wyo.		May 1, 1907
TAYLOR, WILLIAM GAVIN. 301 North Willow St., Waterbury, Conn.		June 5, 1907
WESTON, GEORGE. 181 La Salle St., Chicago, Ill.		June 5, 1907
WOOD, HENRY SHOTWELL. Room 839, Park Row Bldg., New York City		May 1, 1907
WOOD, WARREN POWELL. P. O. Box 38, Lewiston, Idaho.		July 10, 1907

ASSOCIATE MEMBERS.

ANDERSON, WILLIAM TOWNSEND. Supt. of Constr., Turner Constr. Co., 54 West 82d St., New York City		June 5, 1907
ARMSTRONG, ROBERT STUART. Chf. Engr., Brooklyn Plant, Empire Bridge Co., Ft. of Clay St., Brooklyn, N. Y.		Feb. 6, 1907
ASH, LOUIS RUSSELL. 309 Keith & Perry Bldg., Kansas City, Mo.		Dec. 5, 1906
ATWOOD, WILLIAM GREENE. 54 L. S. & M. S. Bldg., Cleveland, Ohio		July 10, 1907
BLIEM, DANIEL WILLIAM. Mgr., Berlin Plant, Am. Bridge Co., East Berlin, Conn.		June 5, 1907
BOWDITCH, JOHN HENRY. Asst. Engr., Staten Island Rapid Transit Ry. Co., New Brighton, N. Y.		July 10, 1907
BRIGGS, HARRY ALSON. Engr. with MacArthur Bros. Co., Katonah, N. Y.		May 1, 1907
BRODIE, ORRIN LAWRENCE. Care, Board of Water Supply, 299 Broadway, New York City		July 10, 1907
BROWN, NORMAN FREED. Asst. Engr. of Constr., P. R. R., 427 Atlantic Ave., Pittsburg, Pa.		June 5, 1907
BUNNEL, WILLIAM CYRUS. Junior Engr., U. S. Engr. Office, Box 155, Manila, Philippine Islands	Jun. Assoc. M.	Oct. 1, 1901 Jan. 2, 1907
CLARKE, WILLIAM DEXTER. Milford, Lassen Co., Cal.		July 10, 1907
COLLINS, GEORGE JAMES SCHILLING. Designing and Constr. Engr., 616 Bee Bldg., Omaha, Nebr.		June 5, 1907

ASSOCIATE MEMBERS (*Continued*).		Date of Membership.
CURTIS, LOREN BRADLEY. 503 Commonwealth Bldg., Denver, Colo		July 10, 1907
DAGGETT, FRED WALLIS. 287 Mill St., Poughkeepsie, N. Y		May 1, 1907
DARROW, FRANK TENNEY. 2026 A St., Lincoln, Nebr		May 1, 1907
DEACON, ERNEST FRANKLIN. Res. Engr., S. & W. Ry., Altapass, N. C		July 10, 1907
DEVLIN, HENRY STRATFORD. 357a Clinton St., Brooklyn, N. Y		June 5, 1907
DONALD, ROBERT L'AMY. Failing Bldg., Portland, Ore		May 1, 1907
DORSEY, WILLIAM HENRY. Engr. and Mgr., Sanford & Brooks Co., 24 Commerce St., Baltimore, Md		June 5, 1907
EASTERBROOKS, PRESTON BURT. Care, Westinghouse, Church, Kerr & Co., 10 Bridge St., New York City.		May 1, 1907
EVERHAM, ARTHUR CASSIDY. Terminal Engr., Detroit River Tunnel Co., M. C. Depot, Detroit, Mich	Jun. Assoc. M.	Feb. 6, 1906 June 5, 1907
FENN, ROBERT WILLSON. Agt., Union Oil Co. of California, Apartado 288, Panama, Panama		July 10, 1907
FIRTH, JOSEPH. Box 290, Charleston, W. Va		June 5, 1907
FISK, CLINTON HINCKLEY. Chf. Engr., Baton Rouge, Hammond & Eastern R. R., 5512 Chestnut St., New Orleans, La		June 5, 1907
FORBES, MURRAY. Greensburg, Pa		June 5, 1907
FOWLER, FRANK GEORGE. Mount Kisco, N. Y		June 5, 1907
FRICKSTAD, WALTER NETTLETON. Instr. in Civ. Eng., Univ. of California, Berkeley, Cal		June 5, 1907
FRISELL, ERIC HJALMAR. Care, Milliken Bros., Apartado 1244, City of Mexico, Mexico		June 5, 1907
GRAY, EDWARD. Engr., M. of W., Southern Ry. Co., 623 Chemical Bldg., St. Louis, Mo		May 1, 1907
GREEN, PAUL EVANS. 315 Giddings St., Chicago, Ill		July 10, 1907
GREGORY, ALFRED COOKMAN. 555 Rutherford Ave., Trenton, N. J		June 5, 1907
GUDE, ALBERT VALDEMAR, JR. Prudential Bldg., Atlanta, Ga.		June 5, 1907
GUSTAFSON, GUSTAF EDWARD. 974 Cuyler Ave., Chicago, Ill.		July 10, 1907
GUSTIN, R. PROSPER. 707 St. Johns Pl., Brooklyn, N. Y.		May 1, 1907
HARRIS, GUY WALTER. 2d and Grant Sts., Amarillo, Tex.		June 5, 1907
HORTON, ALBERT HOWARD. Dist. Hydrography, U. S. Geological Survey, 1330 F St., Washington, D. C	Jun. Assoc. M.	June 3, 1902 Mar. 6, 1907
HOWALT, WILHELM JENS CHRISTIAN. Ridgway, Pa		June 5, 1907
JAHNCKE, ERNEST LEE. 814 Howard Ave., New Orleans, La.		July 10, 1907

ASSOCIATE MEMBERS (*Continued*).

		Date of Membership.
KAUFFMAN, VERNET ALBERT. Asst. Engr., Ferrocarril Rio Grande, Sierra Madre y Pacifico, Nuevo Casas Grandes, Chih., Mexico	Jun. Assoc. M.	Feb. 3, 1903 July 10, 1907
LANCASHIRE, FOREST HENRY. Apartado 224, Monterey, N. L., Mexico		July 10, 1907
LEE, JOHN LOUIS. East Providence, R. I		April 3, 1907
LINARD, DREW JONES. Care, American Consulate, Ceiba, Honduras		July 10, 1907
McGEEHAN, PAUL. Boone, Iowa		July 10, 1907
MAIER, HARRY LUDWIG. Asst. Engr., Street and Sewer Dept., 229 Connell St., Wilmington, Del		June 5, 1907
MAPES, CHARLES MAYNARD. Smith Bldg., 148th St. and Third Ave., New York City		July 10, 1907
MEGGY, ROBERT LOUIS GURDELSTON. Parksville, Edgefield Co., S. C		Feb. 6, 1907
MÖLLER, LOUIS. 130 Lafayette Ave., Detroit, Mich		May 1, 1907
MOORSHEAD, ALFRED LEE. 67 Laurel Ave., Arlington, N. J		April 3, 1907
MORSSEN, CHARLES MICHAEL. Care, Hennebique Constr. Co., 1170 Broadway, N. Y. City		June 5, 1907
NEWBEGIN, PARKER CLEAVELAND. Maintenance Engr., Bangor & Aroostook R. R., Houlton, Me		May 1, 1907
OAKES, JOHN CALVIN. Capt., Corps of Engrs., U. S. A., Galveston, Tex		May 1, 1907
ORTIZ, EDUARDO. Coliseo Viejo No. 6, City of Mexico, Mexico	Jun. Assoc. M.	Nov. 4, 1902 May 1, 1907
PALMER, MARSHALL BARKER. Res. Engr., New York State Barge Canal, Rome, N. Y		June 5, 1907
PARKER, PHILIP À MORLEY. Care, Irrigation Secretariat, Lahore, Punjab, India		Mar. 6, 1907
PARSONS, HAROLD ASHTON. Stamford, Conn		May 1, 1907
PEASE, FREDERICK ATWOOD. Williamson Bldg., Cleveland, Ohio		June 5, 1907
PETERSEN, CHARLES WALTER. Chf. Draftsman, C., R. I. & P. Ry., 802 La Salle St. Station, Chicago, Ill		Feb. 6, 1907
PFLUEGER, ALVIN CYRUS. Asst. Engr., Penn., N. Y. & L. I. R. R., 225 West 33d St., New York City		June 5, 1907
POOLE, CHARLES ARTHUR. Barge Canal Office, DeGraaf Bldg., Albany, N. Y		June 5, 1907
RASTER, WALTHER. With E. C. & R. M. Shankland, 1106 The Rookery, Chicago, Ill	Jun. Assoc. M.	Feb. 4, 1902 Mar. 6, 1907
REED, ALFRED CLARE. Chf. Engr., The Spanish American Iron Co., Mayari, Cuba		June 5, 1907

ASSOCIATE MEMBERS (*Continued*).

		Date of Membership.
REED, WILLIAM BELDEN, JR. Vice-Pres., White Plains Constr. Co., 133 Railroad Ave., White Plains, N. Y.......	Jun. Assoc. M.	Dec. 1, 1896 June 5, 1907
REEL, CHARLES GORDON. Vice-Pres. and Gen. Mgr., Kingston Consolidated R. R. Co., 320 Broadway, Kingston, N. Y..............................		June 5, 1907
REICH, PHILLIP JACOB. Engr., Toledo Plant, Am. Bridge Co., Toledo, Ohio.............................		June 5, 1907
REICHARDT, WALTER FREDERICK. Superv. Engr. of Bldgs., Southwestern Telegraph & Telephone Co., Little Rock, Ark.	Jun. Assoc. M.	Jan. 31, 1905 July 10, 1907
ROBBINS, FRANKLIN HENRY. Aspinwall, Pa............		July 10, 1907
ROBINSON, HERBERT FULWILER. Phœnix, Ariz..........		July 10, 1907
RODENBOUGH, JAMES FOSTER. 571 West 139th St., New York City		April 3, 1907
RUE, MALCOLM ASHER. Structural Engr., Am. Bridge Co., 42 Broadway, New York City...............		June 5, 1907
SAPH, AUGUSTUS VALENTINE. 2226 D. Chapel, Berkeley, Cal.....................	Assoc. Assoc. M.	Oct. 1, 1901 June 4, 1907
SAUERMAN, HENRY BURGER. Coaling Station Engr., 643 East 66th St., Chicago, Ill....................		May 1, 1907
SAVAGE, JOHN LUCIAN. Engr., U. S. Reclamation Service, Boise, Idaho.............................		May 1, 1907
SCHAEFFLER, JOSEPH CARL. Mech. and Civ. Engr., Tremont Bldg., Boston, Mass..	Jun. Assoc. M.	Feb. 28, 1905 June 5, 1907
SCHREIBER, JOHN MARTIN. 448 Summer Ave., Newark, N. J......................................		June 5, 1907
SCHUBERT, FREDERICK CELESTINE. 295 Lincoln St., Portland, Ore..................................		June 5, 1907
SCHWARZE, CARL THEODORE. 490 Tenth St., Brooklyn, N. Y......................................		May 1, 1907
SMITH, EDGAR FIELD. 318 West 126th St., New York City		May 1, 1907
SMITH, LAYTON FONTAINE. Res. Engr. Mgr., Trussed Concrete Steel Co., Wilson Bldg., Baltimore, Md..		June 5, 1907
SPRAGUE, NORMAN SALISBURY. Supt., Bureau of Constr., City Hall, Pittsburg, Pa......................		July 10, 1907
STEPATH, CHARLES UNDERHILL. 154 West 122d St., New York City...........	Jun. Assoc. M.	Feb. 3, 1903 July 10, 1907
STEPHENSON, STUART AUGUSTUS, JR. Asst. Engr., J. G. White & Co., Inc., Caguas, Porto Rico (Res., 77 Maple Ave., New Rochelle, N. Y.)..................	Jun. Assoc. M.	Jan. 3, 1905 July 10, 1907
TILLINGHAST, FREDERICK HOWARD. Care, U. S. Reclamation Service, Belle Fourche, S. Dak............		May 1, 1907

ASSOCIATE MEMBERS (*Continued*).

		Date of Membership.
TUDOR, CLINTON GAMBRILL. P. O. Box 862, Reno, Nev..		May 1, 1907
UNDERHILL, GRANDISON GRIDLEY. Barge Canal Office, Albany, N. Y.		June 5, 1907
VEHRENKAMP, HENRY WILLIAM. Chf. Engr., The Ferro Concrete Constr. Co., 521 Milton St., Cincinnati, Ohio		June 5, 1907
WAUGH, WILLIAM HAMMOND. Chf. Engr., Shenango Traction Co., Greenville, Pa.	Jun.	Oct. 1, 1901
	Assoc. M.	June 5, 1907
WEIDEL, JOSEPH. 1111 Arizona Ave., Trinidad, Colo...		July 10, 1907
WILLIAMS, HOWARD SHAY. 6514 Euclid Ave., Cleveland, Ohio	Jun.	Dec. 1, 1903
	Assoc. M.	June 5, 1907
WILLIS, HARRY PARSONS. Waterford, Saratoga Co., N. Y..		Mar. 6, 1907
WOOD, GEORGE. 150 Union St., High Bridge, New York City		June 5, 1907
WORLEY, JOHN STEPHEN. 613 Nasby Bldg., Toledo, Ohio.		June 5, 1907

ASSOCIATES.

EGLEE, CHARLES HENRY. Gen. Mgr., Ambursen Hydr. Constr. Co., 176 Federal St., Boston, Mass		July 10, 1907
FERRIS, JAMES JOSEPH. 26 Exchange Pl., Jersey City, N. J.		July 10, 1907
GREEN, FREDERICK WILLIAM. Gen. Supt., L. & A. Ry. Co., Stamps, Ark		May 1, 1907
MORE, CHARLES CHURCH. Bridge Dept., C., M. & St. P. Ry. Co. of Wash.; address, Box 93, Washington Station, Seattle, Wash.	Jun.	May 2, 1899
	Assoc.	Feb. 6, 1907
SMITH, CAMERON C. Pres. and Gen. Mgr., Union Steel Casting Co., Pittsburg, Pa.		June 5, 1907
VON SCHRENK, HERMANN. Pathologist, The Missouri Botanical Garden, St. Louis, Mo		July 10, 1907

JUNIORS.

ACKERMAN, ALEXANDER SEYMOUR. Hotel Tivoli, Ancon, Canal Zone, Panama	April 30, 1907
ATWOOD, WILLIAM BARTLETT. R. F. D. No. 9, Lima, Ohio	April 30, 1907
BECKER, RUDOLPH CONRAD. Care, N. Y. Board of Water Supply, Lackawack, N. Y.	April 30, 1907
BELLOWS, DANIEL EVERETT. Little Falls, N. Y.	April 30, 1907
BENEDICT, FARRAND NORTHROP. 15 Fourth St., Long Island City, N. Y.	June 4, 1907
BUNKER, PAUL DELMONT. Key West Barracks, Fla.	June 4, 1907
BURKE, RALPH HANEY. Care, Sanitary Dist. of Chicago, Lockport, Ill.	Dec. 4, 1906

JUNIORS (*Continued*).

	Date of Membership.
BURNS, WALTER ELLIOTT. 2124 Bancroft Way, Berkeley, Cal.	Mar. 5, 1907
BURROUGHS, FREDERIC. Aspinwall, Pa.	June 4, 1907
CAHILL, JOHN RICHARD. 130 Broderick St., San Francisco, Cal.	April 30, 1907
DORRANCE, FRANK YOUNG. Box 349, Aspinwall, Pa.	Feb. 5, 1907
FINCH, JAMES KIP. 509 High St., Easton, Pa.	June 4, 1907
FOUNTAIN, THOMAS LILLY. 143 Liberty St., Room 631, New York City	April 2, 1907
GOODMAN, HARRY MINOTT. 1412 Milvia St., Berkeley, Cal.	June 4, 1907
HALL, HUBERT HARRY. Dawson, Y. T., Canada	April 30, 1907
HARPER, FREDERICK CLAYTON. Engr., Tacoma Eastern R. R., Tacoma, Wash.	April 30, 1907
HARVEY, MICHAEL SMITH. Ruby, Miss.	April 30, 1907
HATCH, FREDERICK NATHANIEL. Smelter, McGill, Nev.	June 4, 1907
HAWLEY, CHARLES RAY. Honey Grove, Tex.	Feb. 5, 1907
HAYES, RALPH DANIEL. 1 Highland Ave., Middletown, N. Y.	June 4, 1907
HUMPHREY, FREDERIC LEABOYD. Care, U. S. Reclamation Service, Las Cruces, N. Mex.	June 4, 1907
JONES, IRVING PAUL. Care, General Delivery, Portland, Ore.	Mar. 5, 1907
NIKIRK, FRANK AUSTIN. 60 W. Virginia St., San José, Cal.	April 2, 1907
O'BYRNE, LEO CHARLES. 996 Washington Blvd., Chicago, Ill.	Feb. 5, 1907
O'HEARN, JOHN LYNCH. Care, Union Constr. Co., Clinton, Okla.	Feb. 5. 1907
PARKER, JAMES LAFAYETTE. 116 Nassau St., Room 901, New York City	April 2, 1907
PATTERSON, EARL. U. S. Reclamation Service, Trust Bldg., El Paso, Tex.	April 30, 1907
PLUMMER, HORACE EDWARDS. 507 Lumber Exchange, Portland, Ore.	April 30, 1907
RANNEY, CHARLES GARFIELD. Leveler, N. Y. State Eng. Dept., Mohawk, N. Y.	April 30, 1907
ROGERS, THOMAS FARWELL. 156 Nineteenth St., Pacific Grove, Cal.	Mar. 5, 1907
SISSON, GEORGE ARTHUR. P. O. Box 1007 (U. S Engr. Office), Manila, Philippine Islands	April 30, 1907
VENSANO, HARRY CHITTENDEN. 1642 Fell St., San Francisco, Cal.	June 4, 1907
WALKER, EDWARD GEORGE. 50 Kingsfield Rd., Watford, Herts, England	April 2, 1907

JUNIORS (*Continued*).	Date of Membership.
WILBANKS, JOHN ROBERT. 820 Security Bldg., St. Louis, Mo.	June 4, 1907
WILLIAMS, LEROY DUNCAN. Lock Box 59, Bevier, Mo.	Feb. 5, 1907
WILLIS, ALBERT JONES. 722 Cherokee St., South Bethlehem, Pa.	June 4, 1907
WOOD, ROBERT WALTER. 26 Post Ave., West New Brighton, N. Y.	April 30, 1907

CHANGES OF ADDRESS.

MEMBERS.

ADAMS, HENRY SEWALL. 108 Ames Bldg., Boston, Mass.

ALBER, HERMANN. 1041 Westlake Ave., Los Angeles, Cal.

ALBERTSON, CHARLES. Chf. Draftsman, The O'Rourke Eng. Constr. Co., 345 Fifth Ave., New York City.

ALDERMAN, CHARLES ALDO. Care, J. G. White & Co., 43 Exchange Pl., New York City.

ALLEN, WILLIAM ANDREW. Care, Garfield Smelting Co., Garfield, Utah.

ANGIER, WALTER EUGENE. 4538 Oakenwold Ave., Chicago, Ill.

ANTHONY, CHARLES, JR. Chf. Engr., Dirks & Dates, Casilla de Correo 95, Bahia Blanca, Argentine Republic.

BARNES, MORTIMER GRANT. Member, Advisory Board of Cons. Engrs., State Hall, Albany, N. Y.

BARRALLY, THOMAS WEBSTER. Res. Engr., Barge Canal Office, North Tonawanda, N. Y.

BIDDLE, JOHN. Maj., Corps of Engrs., U. S. A., 401 Fillmore St., San Francisco, Cal.

BISHOP, HUBERT KEENEY. Care, State Engr. Dept., State Hall, Albany, N. Y.

BLUNT, WILLIAM TITCOMB. Kingfield, Me.

BOLTON, CHANNING MOORE. Cons. Engr.; Chf. Engr., Charlottesville City Water Works; Pres., Charlottesville-Albemarle Ry., Garrison, Mont.

BRAINARD, OWEN. 225 Fifth Ave., New York City.

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(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Blk., Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
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(16) *Engineering and Mining Journal*, New York City, 15c.
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(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
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(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 803 Fulton Bldg., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Electric Railway Review*, Chicago, Ill., 10c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.
(86) *Engineering World*, Chicago, Ill.
(87) *Roadmaster and Foreman*, Chicago, Ill., 10c.

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Steam as a Motive Power for Public Service Vehicles.* Thomas Clarkson. (75) Nov., 1906.
Practical Pyrometry.* Robert S. Whipple. (4) Apr.
Gas Engineering. W. A. Baehr. (Paper read before the Engrs.' Club of St. Louis.) (1) May.
Peat Coke.* Max Toltz. (Paper read before the Civ. Engrs.' Soc. of St. Paul.) (1) May.
History of the Development of the Manufacture of Iron and Steel Sheets.* W. C. Cronemeyer. (58) May.
Sheet Metal Manipulation.* Frank I. Ellis. (58) May.
Some Late Improvements on Compressive Riveters and other Tools.* (58) May.
An Analysis of the Evolution of Modern Tool-Steel.* H. C. H. Carpenter. (11) Serial beginning May 3.
The Burroughs Adding and Listing-Machine.* (11) May 3.

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Mechanical—(Continued).

Valve Gear for High-Speed Engines.* A. Houlson. (47) Serial beginning May 4.
The Most Economical Mean Effective Pressure for Steam Engines.* R. Royds. (Paper read before the Inst. of Engrs. and Shipbuilders in Scotland.) (47) Serial beginning May 4.
The Best Methods of Operating Water Gas Machines. William I. Battin. (Paper read before the Illinois Gas Assoc.) (24) May 6; (83) May 15; (66) May 28.
Economy in Power. A. Stucki. (15) May 10.
Modern Power Plant at the "Argyll Motors" Works, Alexandria, Glasgow.* (26) May 10.
The Production of Coke and Its Application in Domestic Fires.* Paul Schlicht. (29) May 10.
An Electrically-Driven Cement Works.* (73) May 17; (26) May 17.
Effect of Size on the Thermal Efficiency of Explosion Motors. H. L. Callendar. (Paper read before the Inst. of Automobile Engrs.) (47) Serial beginning May 18.
A Floating Derrick for Handling Heavy Rip-rap Stone.* (13) May 23.
The Art of Galvanizing. Alfred Sang. (Paper read before the Amer. Foundrymen's Assoc.) (20) Serial beginning May 23; (62) June 15; (19) Serial beginning July 13.
Dust-Fuel Stokers and Auxiliary Plant. W. R. Harrison. (Paper read before the Leeds Univ. Eng. Soc.) (22) May 24.
Judging Coke from its Appearance.* A. Thau. (Tr. from *Glückauf*.) (22) May 24.
Steel Coal Tipples.* C. W. Brooks. (86) May 24.
Aerial Locomotion.* Alexander Graham Bell. (From the *National Geographic Magazine*.) (19) May 25.
Gas Manufacturing from Peat.* Philip I. Cohen. (66) May 28.
A Review of the United States Geological Survey Fuel Tests Under Steam Boilers.* L. P. Breckenridge. (4) June.
The Properties and Use of Mineral Oils.* P. F. Walker. (9) June.
Efficiency in the Burning of Fuel under the Steam Boiler.* William D. Ennis. (9) Serial beginning June.
The Design of Modern Producers and Gas Engines.* R. E. Mathot. (9) June.
How to Set a Riding Cut-Off Valve.* Hubert E. Collins. (64) June.
First Rateau Regenerator Installed in America.* F. G. Gasche. (64) June.
Formulas for the Flow of Steam in Pipes.* G. F. Gebhardt. (64) June.
Note on Suction Producer Plant.* A. E. Porte. (77) June.
The Design and Construction of Foundry Buildings. Geo. K. Hooper. (Paper read before the Amer. Foundrymen's Assoc.) (14) June 1.
The Woodall-Duckham Vertical Retort-Settings.* (66) June 4.
Purification. G. H. Niven. (Paper read before the Inst. of Gas Engrs.) (66) June 4.
Estimation of Tar Fog and Its Separation from Gases.* R. H. Clayton and F. W. Skirrow. (66) June 4.
Gas-Engine Efficiencies.* Leonard Bairstow. (11) June 7.
Working Experiences with Large Gas Engines.* Cecil A. St. George Moore. (Abstract of paper read before the Soc. of Engrs.) (22) June 7; (47) Serial beginning June 15.
Turbo-Alternators for Sydney, N. S. W.* (22) June 7.
Governors for High-Speed Engines.* A. Houlson. (47) Serial beginning June 8.
A By-Product Coking Plant at Clay Cross.* W. B. M. Jackson. (Paper read before the Inst. of Min. Engrs.) (22) June 14.
Notes on By-Product Coke-Ovens with Special Reference to the Koppers Oven.* A. Victor Kochs. (Paper read before the Inst. of Min. Engrs.) (22) June 14.
How to Build a 5-Horse-Power Stationary Engine.* E. F. Lake. (19) Serial beginning June 15.
Steam Traps. Gordon Stewart. (Abstract of paper read before the Civ. and Mech. Engrs.' Soc.) (47) June 15.
Bench Fuel Economies. F. M. Richards. (Abstract of paper read before the Wisconsin Gas Assoc.) (83) June 15; (66) June 11.
The Mannheim Gas-Works. J. Pichler. (Paper read before the German Assoc. of Gas and Water Engrs.) (66) June 18.
The Vertical Retort-House at the Oberspree (Berlin) Gas-Works.* E. Körting. (Paper read before the German Gas Assoc.) (66) June 18; (24) July 8.
Stamp End Works, Lincoln.* (11) June 21.
The Separation of the Iron Losses in Asynchronous Machines.* Thos. F. Wall. (73) June 21.

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Mechanical—(Continued).

Recent Steam Turbine Developments. W. L. R. Emmet. (Abstract of paper read before the National Elec. Light Assoc.) (14) June 22.
Mechanical Production of Low Temperatures.* Sydney F. Walker. (16) June 22.
Recent Progress in Producer Gas Power Installations.* Godfrey M. S. Tait. (19) June 22.
High Pressure Distribution Development in the United States.* R. M. Searle. (Paper read before the Inst. of Gas Engrs.) (66) June 25; (83) July 1; (24) July 15.
Brown-Boveri Steam Turbines in the Rhenanian-Westphalian Industrial District.* Alfred Gradenwitz. (26) June 28.
The Disposal of Smelter Smoke. Herbert Lang. (16) June 29.
Heat Production and the Constituents of Coal.* S. W. Parr. (16) June 29.
Modern Abrasive Materials and Their Use in Shop Practice.* J. Royden Peirce. (47) June 29.
Superheated Steam.* Thomas Sugden, M. Inst. Mech. Engrs. (Paper read before the South Wales Inst. of Engrs.) (47) Serial beginning June 29.
The Interchange of Heat in Steam-Engine Cylinders. W. F. Cleveland. (9) July.
Gas and Electric Power in Continental Iron and Steel Works.* J. B. van Brussel. (9) July.
General Principles in the Construction of Modern Gas Producers.* R. E. Mathot. (9) July.
The Steam Turbine.* Charles Proteus Steinmetz. (10) July.
Some Recent Developments in Machine Tools.* Joseph Horner. (10) Serial beginning July.
Marshall's Valve Gear.* (21) July.
Electric Crane Lifting Magnets.* (41) July.
Elimination of Friction in Ball Bearings.* J. F. Springer. (64) July.
The Remodeled Rollins Engine.* (64) July.
How Should the Feed Water be Heated?* A. J. Albright. (64) July.
A Steam Plant for Developing One Hundred Horse-power.* James F. Hobart. (64) July.
A Model Hotel Plant.* M. B. Godfrey. (64) July.
Steam-power Plant of One Hundred Horsepower Capacity.* C. R. McGahey. (64) July.
The Gas Power Plant of the Norton Company.* (64) July.
Most Efficient Ratio of Steam Cylinders in Direct-Acting Compound Pumps.* F. F. Nickel. (64) July.
The Steam Engine Versus the Gas Engine. (64) July.
Capacities of Cast Iron Sectional Boilers. Kenneth Gray. (Paper read before the British Inst. of Heating and Ventilating Engrs.) (70) July.
A New Departure in Cooling and Humidifying Textile Mills.* W. H. Carrier. (Abstract of paper read before the Amer. Assoc. of Cotton Mfrs.) (70) July.
Standard Methods in Service, Meter, Appliance and House Fitting.* G. I. Vincent. (Paper read before the Iowa District Gas Assoc.) (24) July 1.
The Adjustment of the Gas Supply to Inverted Burners.* (66) July 2.
Report of the Electrolysis Commission Appointed by the German Gas Assoc. (66) July 2.
Report of the Gas-Meter Commission Appointed by the German Gas Assoc. (66) July 2.
The Carbonisation of Coal, with Special Reference to the By-Product Coking Process.* Ernest Bury. (Abstract of paper read before the Inst. of Gas Engrs.) (22) July 5.
A New Impact Test.* L. W. Page. (Paper read before the Amer. Soc. for Testing Materials.) (14) July 6.
Waste Heat Boilers for Copper Smelting Furnaces.* (14) July 6.
Steam Turbines for Sydney, New South Wales.* (17) July 6.
Santos Dumont's Combined Aeroplane and Airship.* (46) July 6.
Welding and Shaping Link Chains.* (47) July 6.
New Valve Gear for Internal-Combustion Engines.* (47) July 6.
The McMillan Smokeless Furnace Exhibited at Milwaukee.* (62) July 8.
Report of the Cleveland Municipal Committee on the Smoke Nuisance. (62) July 8.
Carbonization of Durham Coking Coal. Andrew Short. (Reprinted from the *Journal* of the Soc. of Chemical Industry.) (66) July 9.
The Lidgerwood Electric Friction-Drum Winches for Car Ferries.* (13) July 11.
Coal and Coke Handling at the Astoria Light, Heat & Power Co.'s Plant, Astoria, L. I.* Alfred Kauffmann. (13) July 11.

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Mechanical—(Continued).

Foundry Design. F. A. Coleman. (Paper read before the Amer. Foundrymen's Assoc.) (20) July 11.
Autogenous Welding.* (20) July 11; (41) July; (18) July 6; (13) June 27.
Beasley's Recording Gas-Calorimeter.* (11) July 12.
Some Practical Points in the Application of the Marine Steam Turbine.* C. A. Parsons and H. Wheatley Ridsdale. (Paper read before the Inst. of Naval Archts.) (11) July 12.
Steam Vehicle Trains for Highway Operation.* (18) July 13.
Amorphous Graphite as a Lubricant. H. C. Woodruff. (18) July 13.
An Aeronautical Observatory.* Alfred Gradenwitz. (19) July 13.
A Traction Wheel with Sinusoidal Tread.* (46) July 13.
Captive Balloons in the German Army and Navy.* Alfred Gradenwitz. (46) July 13.
Roots' Two-Stroke Cycle Internal Combustion Engine.* (47) July 13.
Worthington's Compensating Direct-Acting Engine.* (47) July 13.
Changing a Plant from Artificial to Natural Gas. Geo. W. Barnes. (Paper read before the Natural Gas Assoc. of America.) (83) July 15.
Incandescent Gas Lighting with Special Reference to Inverted Burners. Harold E. Copp. (Abstract of paper read before the British Inst. of Gas Engrs.) (83) July 15.
The Sarco Automatic Combustion Recorder.* (20) July 18.
Tests for Isolating Valves for Steam-Pipes. (11) July 19.
Kermodes Liquid-Fuel System Applied to Babcock and Wilcox Boilers.* (11) July 19.
Compound Pneumatic Hammer.* (12) July 19.
Huddersfield Corporation Electricity Works: Compound Piston Drop Valve Engine.* (12) July 19.
New Machine for Drawing and Loading Coke.* W. M. Nixon. (16) July 20.
Autogenous Welding of Metals. Ernest Schneider. (Abstract from paper read before the Workmen's Union, Chemnitz, Germany.) (19) July 20.
Standard Test Burner for London Gas. Charles Carpenter and James W. Helps. (Paper read before the Inter. Committee on Photometry.) (66) July 23.
Special Derricks and Buckets for the Construction of a Reinforced Concrete Warehouse at Chicago.* (13) July 25.
The Riverside Metal Company's New Rolling Mill Plant.* (20) July 25.
Hydraulic Riveting.* E. W. De Rusett. (Paper read at the Bordeaux Inter. Cong. in Naval Architecture.) (11) July 26.
Engines of the Steam-Yacht *Medusa*.* (11) July 26.
On the Design of Machinery for Very High Pressures.* J. E. Petavel. (11) July 26.
Tests of Staybolts and Staybolt Iron.* E. L. Hancock. (Paper read before the Amer. Soc. for Testing Materials.) (40) July 26.
Power Plant of the West Street Building, New York City.* (14) July 27.
The Steam Power Station of the Twin City Rapid Transit Company, Minneapolis.* (17) July 27.
Test of a Gas Engine Plant in Boston. (27) July 27.
Valve Ellipse Indicator.* (25) Aug.
Some Notes on the Tests at the St. Louis Exposition.* H. H. Vaughan. (From paper read before the Canadian Ry. Club.) (25) Aug.
Fuel Losses in Steam Power Plants. Geo. H. Barnes. (10) Aug.
Safety Appliances in the Engine Room.* William Wallace Christie. (10) Aug.
Modern Jib and Locomotive Cranes.* (41) Aug.
Adjusting the Sturtevant Compound Engine.* Carl S. Dow. (64) Aug.
Producer Gas for Firing Steam Boilers.* A. M. Gow. (64) Aug.
The Operation and Care of Injectors.* W. H. Wakeman. (64) Aug.
A Useful Diagram of Steam Properties.* H. F. Schmidt and W. C. Way. (64) Aug.
Apparatus for Analyzing Flue Gases.* (64) Aug.
Suction Gas Producer Plant at Rocky Ford, Colo.* (64) Aug.
Different Styles of Connecting-Rods Compared.* C. R. McGahey. (64) Aug.
A Wire-Wound Wood-Rim Fly-Wheel.* E. E. Clock. (64) Aug.
Approved Proportions of Flange Couplings, Clutches and Wrenches (Tables).* John D. Adams. (64) Aug.
Gravel Screening and Washing Plants.* (13) Aug. 1.
Methods Followed in Making Becker-Brainard Milling Machine Castings.* Henry M. Lane. (20) Aug. 1.
High Pressure Transmission (of Gas). R. H. Lawlor. (Paper read before Iowa District Gas Assoc.) (83) Aug. 1.
Standard Methods in Pipe Fitting (Gas).* G. I. Vincent. (Paper read before the Iowa District Gas Assoc.) (83) Aug. 1.
Motor Starting Devices for Gasoline Automobiles.* Harold H. Brown. (19) Aug. 3.

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Mechanical—(Continued).

The Present Status of Candle Power Standards for Gas. C. H. Stone. (Paper read before the Illuminating Eng. Soc.) (24) Aug. 5.
Advantages of Mechanical Stoking as Smoke Abaters.* Paul M. Chamberlain. (Lecture before the International Assoc. for the Prevention of Smoke.) (62) Aug. 5.
Etat Actuel de l'Industrie Frigorifique.* Ch. Lambert. (32) Apr.
Carburateurs Divers.* (37) Apr.
Train Automobile de la Société Freibahn pour le Transport des Marchandises.* A. Bidault des Chaumes. (33) Apr. 27.
Représentation du Fonctionnement Théorique des Gazogènes au Coke.* Rodolphe Soreau. (32) May.
Des Huiles à Graisser.* Ch. Baron. (32) May.
Note sur l'Allumage Electrique des Moteurs à Gaz et à Pétrole.* H. Lhonoré. (37) May.
Gazogène à Combustible Pulvérisé, système Marconnet.* (33) May 11.
La Voiture Pétroléo-Electrique. Système Kriéger.* F. Drouin. (33) June 1.
Appareil pour Faire Circuler l'Eau Méthodiquement dans les Chaudières Ignitubulaires ou à Foyers Intérieurs.* (33) June 22.
Production Economique de la Force Motrice au Moyen de Gaz Métallurgiques.* Ch. Dantin. (33) June 29.
Un Dirigeable Allemand: *Le Zeppelin*.* G. Espitallier. (33) July 6.
Machine à Fabriquer les Bouteilles en Verre, Système Leistner.* (33) July 13.
Comparaison entre les Grues Hydrauliques et les Grues Electriques.* R. Gasquet. (33) July 27.
Die Beanspruchung von Drahtseilen. J. Isaachsen. (48) Apr. 27.
Selbsttätiger Gegenstrom- und Wasserumlauf-Erzeuger von Kunert für Flamm- und Heizrohrkessel.* Dr. Förster. (48) Apr. 27.
Ein Modernes Platinen-Triowalzwerk.* (50) May 8.
Temperaturspannungen in Hohlzylindern.* Rudolf Lorenz. (48) May 11.
Ergebnisse der Untersuchung eines bei der Druckprobe Aufgerissenen Kesselbleches.* C. Bach. (48) May 11.
Neuere Ziele und Erfolge des Deutschen Wärmekraftmaschinenbaues.* H. Dubbel. (48) Serial beginning May 18.
Ueber Gasgeneratoren.* (Discussion.) (50) June 5.
Rauchverbrennung.* (82) June 29.
Zur Frage der Rissbildung in Kesselblechen.* Eichhoff. (50) July 3.
Hebe- und Transportmittel in Stahl- und Walzwerksbetrieben.* G. Stauber. (Paper read before the Verein Deutscher Eisenhüttenleute.) (50) July 10.
Taylors Untersuchungen über Rationelle Dreharbeit. A. Wallichs and O. Petersen. (50) July 17.
Wärmespannungen und Rissbildungen.* Carl Sulzer. (48) July 27.
Hochbau-Mastenkrane.* Georg W. Koehler. (48) July 27.

Metallurgical.

Fine Grinding of Ore by Tube-Mills, and Cyaniding at El Oro, Mexico.* G. Caetani and E. Burt. (56) Vol. 37.
The Amalgamation of Gold-Ores.* Thomas T. Read. (56) Vol. 37.
Notes on the Gayley Dry-Air Blast-Process.* C. A. Meissner. (56) Vol. 37.
Piping in Steel Ingots.* N. Lilienberg. (56) Vol. 37.
The Washoe Plant of the Anaconda Copper-Mining Co. in 1905.* L. S. Austin. (56) Vol. 37.
Heat-Treatment of Steels Containing Fifty Hundredths and Eighty Hundredths Per Cent. of Carbon.* C. E. Corson. (56) Vol. 37.
The Crystallography of Iron.* F. Osmond and G. Cartand. (56) Vol. 37.
The Cyanidation of Raw Pyritic Concentrates. Frank C. Smith. (56) Vol. 37.
The Lime-Roasting of Galena. W. R. Ingalls. (56) Vol. 37.
The Secondary Enrichment of Copper-Iron Sulphides. Thomas T. Read. (56) Vol. 37.
The Mining, Preparation and Smelting of Virginia Zinc-Ores.* Thomas Leonard Watson. (56) Vol. 37.
Stamp-Mill Reduction-Plant of the New Kleinfontein Company, Limited, Witwatersrand, Transvaal. Edward John Way. (63) Vol. 168.
Vanadium Steels in Railroad Practice. J. Kent Smith. (Extracts from paper read before the Central Ry. Club.) (18) May 4.
Ore Concentration by Oil.* (12) May 10.
Vacuum-flotation Process for Concentration.* Alexander Stanley Elmore. (16) May 11.
Magnetic Separation of Iron Ore in Sweden.* G. Walfrid Petersson. (Tr. by N. V. Hansell.) (16) May 11.
Tin Ore Dressing Plant, East Pool, Cornwall.* Edward Walker. (16) May 18.
Compression of Steel Ingots by Wire Drawing.* E. L. Zalinski. (From the *Journal of the U. S. Artillery*.) (15) May 24.

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Metallurgical—(Continued).

Chrome Plant of the U. S. Metals Refining Company.* Lawrence Addicks. (16) May 25.
Change of Structure in Iron and Steel.* Wm. Campbell. (3) June.
Milling at Gladstone, Colo.* Geo. P. Scholl. (45) June.
Stack Extension of Copper Queen Smelter, Douglas, Ariz.* (45) June.
The Use of Graphic Formulas in Metallurgical Calculations.* D. H. Browne. (Paper read before the Canadian Inst.) (45) June.
Zinc Oxide and Zinc-Lead Pigment Manufacture.* William F. Gordon. (16) June 1.
Behaviour of Carbon and Phosphorus in Steel.* Henry M. Howe. (16) June 8.
Method for Analysis of Gold-Silver Bullion. J. E. Clennell. (16) June 8.
Practice at the Osceola Mill, Lake Superior.* Lee Fraser. (16) June 22.
Extract of Report on the Methods Used to Avoid Piping in Steel Ingots, As Applied in the Hungarian Government Steel Foundries at Diosgyör.* Albert Obholzer. (3) July; (62) July 22.
A Modern Copper Converter.* G. B Shipley. (45) July.
The Systematic Treatment of Metalliferous Waste. L. Parry. (68) Serial beginning July 6.
The Electrolytic Process of Copper Recovery. Walter Stoeger. (Tr. from *Metallurgie.*) (68) Serial beginning July 6.
Rail Steel as Manufactured by the Continuous Open-Hearth Process at Cargo Fleet.* Benjamin Talbot. (Paper read before the Amer. Soc. for Testing Materials.) (22) July 12.
Milling "Sheet Ground" Ore in Joplin (Mo.) District.* Doss Brittain. (16) July 13.
Vanadium Steel. J. Kent Smith. (62) July 15.
An Example of Blast Furnace Reconstruction (Richard Heckscher & Sons Company's Plant).* (20) July 25.
The Modern American Blast Furnace.* Bradley Stoughton. (16) Serial beginning July 27.
Copper-Smelting Practice in the Boundary District, British Columbia.* Frederic Keffer. (9) Aug.
The Largest Copper Smelting Plant in the World.* (13) Aug. 1.
L'Aluminothermie et ses Applications.* J. Feugères. (34) May.
L'Utilisation Industrielle de la Métallographie Microscopique.* Léon Guillet. (33) Serial beginning June 15.
Cubilot à Récupération, Système A. Baillot.* Ch. Dantin. (33) June 15.
L'Electro-Sidérurgie.* Jean Escard. (34) Serial beginning July.
Die Hochofen-, Stahl- und Walzwerksanlage der "Società Anonima degli Alti Forni e Fonderia di Piombino."* Fritz Lürmann, Jr. (50) May 1.
Chrom-Nickelstähle. Kedesdy. (Abstract from article by Guillet in *Revue de Métallurgie.*) (50) May 8.
Ueber Gasgeneratoren. Johannes Körting. (Paper read before the Verein Deutscher Eisenhüttenleute.) (50) May 15.
Chemische und Metallographische Untersuchungen des Hartgusses.* H. Wedding and Fritz Cremer. (50) Serial beginning June 12.
Erzrösten.* Carl Wetzel. (82) Serial beginning June 29.
Das Turbinengebläse von C. A. Parsons als Hochofengebläsemaschine.* Julius Fürstenau. (48) July 20.
Ueber den Augenblicklichen Stand Unserer Kenntnisse der Erstarrungs- und Erkaltungsvorgänge bei Eisenkohlenstofflegierungen. P. Goerens. (50) July 24.

Military.

105-Millimetre and 120-Millimetre Quick-Firing Field Howitzers.* (11) May 10.
Birmingham Small Arms.* (12) May 10.
The Coventry Ordnance Works, Limited.* (12) Serial beginning May 31.
The New Vickers-Maxim Automatic Rifle-Calibre Gun.* (46) Aug 3.

Mining.

Methods of Mining, Hauling and Screening at the Mines of the Aldrich Mining Company, at Brilliant, Alabama.* T. H. Aldrich. (56) Vol. 37.
The Relative Merits of Large and Small Drilling Machines in Development Work.* Frederick T. Williams. (56) Vol. 37.
The Beard-Mackie Sight-Indicator for the Measurement of Marsh-Gas in Collieries.* M. H. Harrington. (56) Vol. 37.
Bibliography of Coal-Washing. Samuel S. Wyer. (56) Vol. 37.
Screens for Sizing. Ernest A. Hersam. (56) Vol. 37.
The Mining, Preparation and Smelting of Virginia Zinc-Ores.* Thomas Leonard Watson. (56) Vol. 37.

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Mining—(Continued).

A Novel Method of Mining Kaolin. Albert R. Ledoux. (56) Vol. 37.
Gold-Dredging in the Urals, with Notes on Dredging in Siberia.* William H. Shockley. (56) Vol. 37.
The Hanley Cage Guardian.* (59) Vol. 29, Pt. 4.
Some Notes on the Mechanical Equipment of Collieries.* E. M. Hann. (75) Oct., 1906.
Notes on the Electrical Installation at Swalwell Garesfield Colliery.* Jackson Swindle. (Paper read before the National Assoc. of Colliery Mgrs.) (22) Apr. 26.
Electric Power in Durham Collieries.* (26) Serial beginning Apr. 26.
Colliery Hoisting, Haulage and Power Systems.* Franz Erich Junge. (16) May 11.
Four Tests of a Capell Mine Ventilating Fan.* John B. Thomson. (16) May 25.
The Electrical Equipment of the Yak Tunnel.* Robert E. Renz. (16) May 25.
Methods Used in Surveys of Coal Mines.* L. D. Tracy, Assoc. M. Am. Soc. C. E. (13) May 30.
Methods of Mining in the Boundary District, British Columbia.* Frederic Keffer. (9) June.
Stresses in Hoisting Ropes. James F. Howe. (45) June.
Hydraulic Mining.* William W. Harts. (45) June.
Process of Coal Washing.* Samuel Diescher. (58) June.
Description of Washing Plants in Operation.* W. G. Wilkins. (58) June.
Mining Coal. Lee C. Moore. (58) June.
The Electric Power Installation at Grangesberg Iron Mines, Sweden.* G. Ralph. (Abstract.) (77) June.
Colliery Explosions and Their Causes.* James T. Beard. (16) June 1.
An Alternating-Current Coal-Mining Installation.* T. W. Sprague and C. K. Stearns. (16) June 8.
Operation and Equipment of the St. Clair Colliery.* Floyd W. Parsons. (16) June 15.
The Progress of Mining in Great Britain in Recent Years. M. Deacon. (Abstract of paper read before the Inst. of Min. Engrs.) (68) Serial beginning June 22.
The Tibetan Goldfields.* Malcolm Maclaren. (68) June 22.
Recent Improvements at the Clausthal Mines.* Bergrat Schennen. (68) June 22.
Gold-Dredging Practice at Ruby, Montana.* J. P. Hutchins. (16) Serial beginning June 29.
The Schuyler Mine.* J. H. Granbery, Assoc. M. Am. Soc. C. E. (3) Serial beginning July.
Explosion of Air Locomotive.* (45) July.
Concrete Roof Supports.* (45) July.
Lead-Silver Deposits of Mowry, Ariz., the Caving System of Mining 80 Per Cent. of the Ore without Timbering.* R. B. Brinsmade. (45) July.
The Panel Retreating System.* S. J. Jennings. (45) July.
Wood *versus* Iron for Pipe Lines in Coal Mines. John H. Haertter. (16) July 6.
Modern Methods of Washing Bituminous Coal.* Floyd W. Parsons. (16) July 6.
Alternating Current in Coal-Mining Operations.* George R. Wood. (16) July 6.
Working Flat and Pitching Anthracite Seams.* M. S. Hachita. (16) July 6.
Electric Installation at the Cambrian Collieries Limited.* (57) July 12.
Practical Experiments in Coal-Mine Ventilation. W. D. Owens. (16) July 13.
The Syracuse Shaft on the Mesabi: How a Shaft Was Sunk Through Quicksand by Pneumatic Process.* (16) July 13; (14) July 13.
The Turned-back Shaft at the Salisbury Mines.* Reginald Meeks. (16) July 13.
A Complete Description of Washing Plants in Operation.* W. G. Wilkins. (62) July 15.
Ventilation of Shafts During Sinking Operations.* (22) July 19.
Fan Ventilators for Mines. Robert Grimshaw. (16) July 20.
The Caving System on the Menominee Range.* Reginald Meeks. (16) July 20.
Some Practical Points on Mine Surveying. Laurence C. Hodson. (Reprinted from *Iowa Engineer*.) (16) July 20.
Stoping with the Air-Hammer Drill.* G. E. Wolcott. (16) July 20.
The Treatment of Anthracite Coal.* (22) July 26.
Ferro-Concrete Lining for Mine Galleries.* (From *Zeitschrift für Berg-, Hütten- und Salinenwesen.*) (57) July 26.

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Mining—(Continued).

Rack-rail Haulage in Coal Mines.* George E. Lynch. (16) Aug. 3.
Subsidence in Underground Mines.* Alexander Richardson. (Abstracted from *Journal*, Chemical, Metallurgical and Mining Soc. of South Africa.) (16) Aug. 3.
Revêtements de Galeries en Béton Armé aux Mines de Béthune.* Lombois. (Abstract from *Bulletin de la Société de l'Industrie Minérale.*) (33) June 8.
L'Enrichissement des Minérais par l'Huile procédé Elmore.* (33) June 29.

Miscellaneous.

Principle and Operation of the Féry Radiation Pyrometer.* C. H. Wilson and Frederick Maeulen. (6) Apr.
Building a Town Site by Suction Dredge.* Day Allen Willey. (46) May 25.
Pyrometry in Modern Workshop Practice.* Chas. R. Darling. (Abstract of Lecture at the City and Guilds Technical College, Finsbury, E. C.) (12) June 14.
The Enforcement of Specifications. Charles B. Dudley. (Paper read before the Amer. Soc. for Testing Materials.) (14) June 29; (13) July 4.
"Flexibles" with Notes on the Testing of Rubber.* Alfred Schwartz. (77) July.
Engineering Education. (Abstracts of papers read before the Soc. for the Promotion of Eng. Education.) (18) July 6.
Some Facts About Dynamite: The Chemistry of a Powerful Explosive. (19) July 20.
Comparisons of Light-Standards: Report made by the National Physical Laboratory to the Inst. of Gas Engrs.* (66) July 23.
Determining Volumes of Coal in Bins and Piles.* Charles Enzian. (16) July 27.
De la Dispersion Artificielle du Brouillard.* M. Dibos. (32) Mar.
Le Papier et sa Fabrication à Travers les Ages.* A. Blanchet. (32) May.

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First Prize Paper on Best Methods of Draining Roadbeds.* Albert Cramblit. (87) May.
The Maintenance of Asphalt Pavements. S. Whinery, M. Am. Soc. C. E. (13) May 9.
Tar Macadam Pavement in Duluth, Minn. E. K. Coe. (13) May 30.
The Development of Street Pavements.* George W. Tillson. (3) June.
Brick Pavements.* (60) June.
Second Prize Paper on Best Methods of Draining Roadbed.* T. J. Scanlin. (87) June.
Recent Progress in the Asphalt Paving Industry. Clifford Richardson. (Abstract of paper read before the Soc. of Chemical Industry.) (14) June 1.
The Use of Tar on Roadways. H. P. Maybury. (Paper read before the Inst. of Gas Engrs.) (66) June 25.
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The Municipal Works of Gary, Ind.* (14) July 20.
Notes on Tar Macadam. C. F. Wike. (Abstract of paper read before the Assoc. of Municipal and County Engrs.) (66) July 23.
Cement Filler for Brick Pavements.* (60) Aug.
Rapport d'Ensemble sur les Moyens Employés jusqu'ici pour Combattre la Poussière des Routes, Presenté à la Commission d'Etudes Instituée par M. le Ministre des Travaux Publics. Le Gavrian. (43) 1907, Pt. II.

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Comparison of American and Foreign Rail-Specifications, with a Proposed Standard Specification to Cover American Rails Rolled for Export. Albert Ladd Colby. (56) Vol. 37.
The Simplon Tunnel.* Francis Fox. (63) Vol. 168.
The Design of Wayside Stations for Single Lines of Railway.* Frederick George Royal-Dawson. (63) Vol. 168.
Railway-Motor-Car Traffic.* T. Hurry Riches and Sidney B. Haslam. (75) Dec., 1906.
Lighting of Railway Premises: Indoor and Outdoor.* Henry Fowler. (75) Dec., 1906.
Single Phase Railways.* F. E. Wynne. (2) Apr.
Vibrations in Passenger Trains From High Speed Electric Lighting Engines.* F. W. Huels. (4) Apr.
Notes on Three-Phase Traction. Gerard B. Werner. (6) Apr.
Electric Train Lighting. O. W. Ott. (61) Apr.
Gasoline Motor Cars for Railway Service.* W. R. McKeen, Jr. (65) Apr.

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Regenerative Control of Electric Tramcars and Locomotives.* Alfred Raworth. (77) Apr.
The Modern Locomotive.* Paul T. Warner. (3) May.
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Low Pressure Pneumatic Signalling at Ermont; Northern Railway of France.* (21) May.
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Line Changes and Extensions of the Oregon Railroad & Navigation Company's System in Oregon and Washington.* W. P. Hardesty. (13) May 16.
Rack Locomotive for the TransanJine Railway.* (11) May 17.
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Prussian State Railway Signals.* W. H. Pockels. (15) May 24.
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Physical Conditions which Affect Rail Making.* A. W. Heinle. (62) May 25.
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A Vital Electric Traction Problem.* (Abstract from *Electrical Age.*) (73) May 31.
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The New Roof at Charing Cross Terminus, South Eastern Railway.* Chas. S. Lake. (21) June.
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All Steel Passenger Service Cars, Pennsylvania Railroad.* (25) Serial beginning June; (18) Serial beginning June 8; (17) June 8; (40) June 7; (13) June 20; (15) June 14.
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Air Brakes on the New York Central Electrical Equipment.* S. W. Dudley. (Extracts from paper read before the Air Brake Assoc.) (18) June 1.
Recent Developments in Air Brake Control Apparatus.* F. H. Parke and S. W. Dudley. (15) June 7.
A Solution of the Oil-Burning Locomotive Problem.* Harrington Emerson. (15) June 7.
De Glehn Compound for the Paris-Orleans Railway.* (15) June 7.
Changing the Gage on the Louisville and Nashville.* Reuben Wells. (15) June 7.
Pacific Locomotive for the Atlanta & West Point.* (15) June 7; (40) July 19.
Compression in Locomotive Cylinders and Means for its Relief.* H. G. Manning. (15) June 7.
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New Tank Locomotive for the Midland Railway.* (47) June 15.
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A Test of Insulators for an Exceptional Service.* Sidney Sprout. (72) June 15.
New Steel Cars of the Hudson Companies.* Hugh Hazleton. (72) June 15; (40) June 14; (15) June 14; (17) June 8.
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Four-Cylinder Compound Express Locomotive, Danish State Railways.* (11) June 28.
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Solid Steel Wheels for Passenger Cars. George L. Fowler. (Paper read before the Master Car Builders' Assoc.) (15) June 28.
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Standard Specifications for Steel Rails. (Recommended by the Committee on Standard Specifications for Iron and Steel of the Amer. Soc. for Testing Materials.) (14) June 29; (15) July 5; (13) July 4.

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Die Maschinellen Anlagen beim Bau des Tauerntunnels.* K. Brabbée. (48) May 25; (53) Serial beginning June 7.
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Die Einführung des Elektrischen Zugbetriebes auf den Berliner Stadt-, Ring- und Vorortbahnen. W. Reichel. (48) Serial beginning June 22.
Der Antriebvorgang bei Lokomotiven.* J. Jahn. (48) Serial beginning July 6.

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The Efficiency of the Shone System of Pumping.* Charles Leslie Cox. (63) Vol. 168.

Big Four Sanitary Sewage Disposal System.* (86) May 3.

The Pollution of New York Harbor. George C. Whipple. (Abstract of paper read before the N. Y. County Homeopathic Medical Assoc.) (14) May 25; (13) May 28.

The Admission of Trade Wastes into the Sewers of Reading, Pa. (14) May 25.

Street Cleaning in the Central Business District of Chicago.* (14) May 25.

The Health of Employees in the New York Subway. George A. Soper. (7) June.

English, German and Swiss Destructors Plants.* Frank C. Perkins. (60) June.

Data for Heating Calculations. Wm. Kent. (Paper read before the Nat. Assoc. of Master Steam and Hot Water Fitters.) (70) Serial beginning June.

Heating and Ventilating of the Title Guarantee Trust Building, New York.* (14) June 1.

The Comparative Disposition of Organic Matter by Sand, Contact and Sprinkling Filters. H. W. Clark. (Abstract of paper read before the Amer. Pub. Health Assoc.) (13) June 6.

Use of Gas from a Hygienic Standpoint. Vivian B. Lewes. (66) June 25; (24) Aug. 5.

A Judicial Review of American Stream Pollution Decisions. (14) June 29.

The Atmosphere of Cities. H. Henriet. (19) July 6.

Electrically-Driven Sewage Pumping Plant at Salem, Mass.* (27) July 6.

Official Report on Typhoid Fever in Washington, D. C., in 1906. (Abstract.) (13) July 11.

The Testing and Hygienic Efficiency of Gas Fires.* Jno. H. Brearley. (Abstract of paper read before the Inst. of Gas Engrs.) (12) July 12.

Heating and Ventilating the Hotel Knickerbocker, New York City.* (14) July 13.

Large Riveted-Steel Sewers in Jersey City, N. J.* (14) July 13.

Mosquito Work and Malaria in the Panama Canal Zone. (Extract from Report, Dept. of Health, Isthmian Canal Comm.) (13) July 18.

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New Sewage Pumping Station at Chicago: Description of the Installation of the Thirty-ninth Street Pumping Station, on the South Side.* Athburn W. Meltrose. (64) Aug.

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Siphon de Chasse Parenty.* Parenty. (43) 1907, Pt. II.

Mémoire sur un Régulateur de Débit Système Parenty.* Parenty. (43) 1907, Pt. II.

Les Siphons Sous-Marins des Egouts de Copenhague.* G. Piou de Saint-Gilles. (33) May 18.

Calcul des Installations de Chauffage par l'Eau Chaude à Basse Pression.* E. Mathieu. (30) June.

Die Tunnelstrecken der Neuen Stammsiele in Hamburg.* Curt Merckel and Unger-Nyborg. (51) Serial beginning May 4.

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Internal Stresses and Strains in Iron and Steel. Henry D. Hibbard. (56) Vol. 37.

A New Colorimeter for the Determination of Carbon in Steel.* Charles H. White. (56) Vol. 37.

Distribution of Stresses in Plate-Girders.* Cyril Walter Lloyd-Jones. (63) Vol. 168.

Reinforced Concrete: Its Limitations.* Carl Gayler. (Paper read before the Engrs. Club of St. Louis.) (1) Apr.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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REINFORCED CONCRETE TOWERS.

By D. W. Krellwitz, Jun. Am. Soc. C. E.

To be Presented October 2d, 1907.

Electrical energy is now being delivered by transmission lines to cities many miles distant from its source. The wires carrying the current are supported on towers which must conform to the requirements of navigation when rivers and canals are crossed, that is:

"There must be ample overhead clearance from the water to the nearest point of the transmission wires, so that vessels with high masts can pass under the wires." (Fig. 1.)

This paper describes the reinforced concrete towers, built for The Lincoln Light and Power Company, on each side of the old Welland Canal, in the Province of Ontario, to transmit current from the transformer building to St. Catharines, Ontario, Canada.

These towers are 150 ft. high, 142 ft. being above ground. They are 11 in. square at the top and 31 in. square at the bottom, with chamfered corners, and are provided with foot steps and rungs. Each tower carries sixteen No. 1 bare copper wires on glass insulators. The cross-arms are $3\frac{1}{4}$ by 4 in., and are 10 ft. long, and beneath them there is a working platform about 10 ft. long and 5

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

ft. wide. The span over the canal is 76 ft., but adjacent to this span there is a span of about 300 ft. On one of the towers the wires run vertically, being fastened to two frames, 42 and 82 ft., respectively, from the top. At the top of this tower there is a heavy pull parallel to the line, which at this point makes a right-angled turn.

The collapse of a tower on a transmission line, caused by a storm, would be a very serious matter, and would be likely to cause lawsuits, the loss of light and power customers, and, perhaps, loss of life, on account of the dangerous currents.

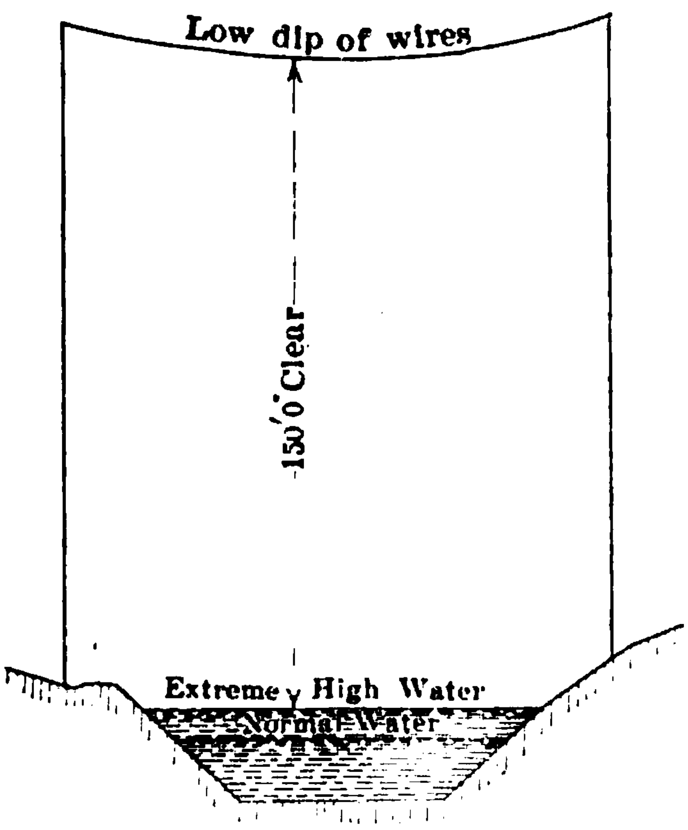

FIG. 1.

These towers have been designed to withstand wind pressures of 30 lb. per sq. ft. on flat surfaces, and 15 lb. per sq. ft. on cylindrical surfaces. A liberal assumption was made by calculating the exposed surface of the wire as its diameter plus a coating of ice $\frac{3}{8}$ in. thick multiplied by the span. As the greatest wind pressures in that part of the country have never exceeded an average of 30 lb. per sq. ft. on large areas, it is reasonable to believe that these towers are absolutely safe.

The following conditions were observed in designing the towers:

Case I.—Tower, without wires, and not guyed; to withstand a pull of 2 000 lb. at the top;

Case II.—Guyed tower; to withstand full wind pressure plus pulls transverse to the line, due to the wires;

Case III.—In case of the breakage of all the line wires—for 300 ft. span—the total pull to be taken on the guyed tower plus full wind pressure on the tower.

The calculations are based on the following assumptions:

First.—The section plane before bending remains plane after bending; that is, the stress of any fiber is proportional to its distance from the neutral axis (Fig. 2).

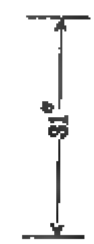

FIG. 2.

Second.—The applied forces are perpendicular to the plane of the neutral axis.

Third.—The tensile strength of the concrete is neglected.

Fourth.—There are no initial strains.

$\dfrac{\text{Modulus of elasticity of steel}}{\text{Modulus of elasticity of concrete}}$ =.........	15
Ratio of cross-section of steel in tension to cross-section of beam above this steel...	0.01129
Ratio of cross-section of steel in compression to cross-section of beam above the steel in tension	0.01129
Compressive stress in the extreme fiber of concrete.....	600 lb. per sq in.
Tensile stress in steel..........	16 000 lb. " " "
Compressive stress in steel.....	6 350 lb. " " "
Ratio of depth of steel in compression to depth of steel in tension.....................	0.10714
Depth of steel in tension..................	28 in.

Case I.—The bending moment is $2\,000 \times 142.0 = 284\,000$ ft-lb. The distance from the compressive surface to the neutral axis, when the maximum allowable bending moment is applied, is:

$$\left[\sqrt{2 \times 15 \times (0.01129 + 0.01129 \times 0.10714) + 15^2 \times (0.01129 + 0.01129)^2} - 15 \times (0.01129 + 0.01129)\right] \times 28 = 10.108 \text{ in.}$$

The ratio of depth of neutral axis to depth of steel in tension is.. 0.3610

The moment of resistance is:

Taking moments about the center of compression in concrete,

$$\frac{31 \times 28^2 \times \left[16\,000 \times 0.01129 \times \left(1 - \frac{0.361}{3}\right) + 6\,350 \times 0.01129 \times \left(\frac{0.361}{3} - 0.10714\right)\right]}{12} = 323\,700 \text{ ft-lb.}$$

Taking moments about the center of compression stress in the steel,

$$\frac{31 \times 28^2 \times \left[16\,000 \times 0.01129 \times (1 - 0.10714) - \frac{600 \times 0.361}{2} \times \left(\frac{0.361}{3} - 0.10714\right)\right]}{12} = 323\,700 \text{ ft-lb.}$$

The compressive stress in the extreme fiber of the concrete, due to bending, is:

$$\frac{284\,000 \times 12}{31 \times 28^2 \times \left[\frac{0.361}{2} \times \left(1 - \frac{0.361}{3}\right) + \frac{15 \times 0.01129 \times (0.361 - 0.10714) \times (1 - 0.10714)}{0.361}\right]} = 529 \text{ lb. per sq. in.}$$

The compressive stress in the steel, due to bending, is:

$$\frac{284\,000 \times 12}{31 \times 28^2 \times \left[0.01129 \times \left(\frac{1 - 0.361}{0.361 - 0.10714}\right) \times \left(1 - \frac{0.361}{3}\right) + 0.01129 \times \left(\frac{0.361}{3} - 0.10714\right)\right]} = 5\,578 \text{ lb. per sq. in.}$$

The direct compressive stress in the concrete, caused by the dead load of the tower above the point of maximum stress, due to bending, is:

$$\frac{63\ 300}{(19.6 \times 15) + (31^2 - 19.6)} = 51 \text{ lb. per sq. in.}$$

19.6 sq. in. = area of four rods

63 300 lb. = dead load.

The direct compressive stress in the steel, caused by the dead load of the tower above the point of maximum stress, due to bending, is:

$$\frac{63\ 300}{19.6 + \dfrac{31^2 - 19.6}{15}} = 769 \text{ lb. per sq. in.}$$

The combined compressive stress in the extreme fiber of the concrete is:

$$529 + 51 = 580 \text{ lb. per sq. in.}$$

The combined compressive stress in the steel is:

$$5\ 578 + 769 = 6\ 347 \text{ lb. per sq. in.}$$

Case II.—

Diameter of wire................	0.3 in.
Thickness of ice coating........	0.75 "
Total....................	1.05 in. = 0.087 ft.

Wind pressure per linear foot of wire $= 0.087 \times 15 = 1.3$ lb.

Weight of wire per foot....................	0.27 lb.
Weight of ice load per foot................	0.324 "
Total..................................	0.594 lb.

The resultant force, normal to the line, is:

$$\sqrt{0.594^2 + 1.3^2} = 1.43 \text{ lb. per ft. of wire;}$$

and the total resultant force is:

$$\left(\frac{300 \text{ ft. span}}{2} + \frac{76 \text{ ft. span}}{2} \times 1.43\right) \times 16 \text{ wires} = 4\ 300 \text{ lb.}$$

Vertical force on tower, due to resultant force	5 000 lb.
Weight of cross-arms and platform........	600 "
Dead load of tower above the point of maximum fiber stress due to bending......	63 300 "
Total..............................	68 900 lb.

Area of four steel rods $= 19.6$ sq. in.

The fiber stress in the concrete, due to direct compression, is:

$$\frac{68\,900}{(19.6 \times 15) + (31^2 - 19.6)} = 56 \text{ lb. per sq. in.}$$

In calculating the fiber stress due to bending, caused by wind pressure, the towers are considered as held at the top with steel guys and fixed at the base (Fig. 3).

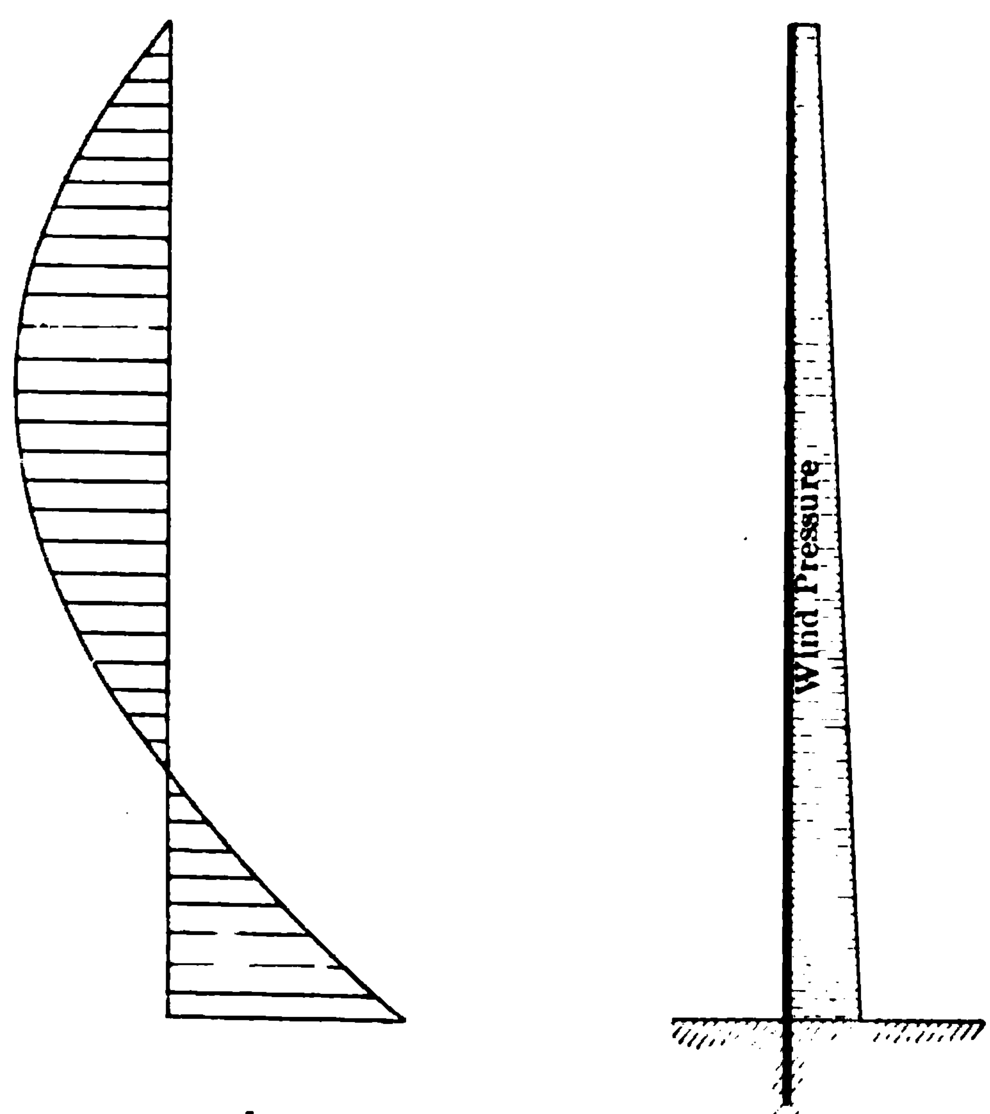

FIG. 3.

The wind pressure is:

$$247 \text{ sq. ft.} \times 30 \text{ lb.} = 7\,410 \text{ lb.}$$

and the maximum moment due to wind is 118 200 ft-lb.

The fiber stress due to direct compression is	56 lb. per sq. in.
The fiber stress compression due to bending is	222 " " " "
Total compression in the concrete.	278 lb. per sq. in.

Case III.—

The area of one wire is 0.07 sq. in., and, in case all the line wires break, the pull is:

$$0.07 \times 16 \times 60\,000 = 67\,200 \text{ lb.}$$

The vertical force on the tower is........	50 000 lb.
The weight of the cross-arms and platform is	600 "
The dead load of the tower, above the point of maximum fiber stress, due to bending, is	63 300 "
Total...........................	113 900 lb.

The fiber stress in the concrete due to direct compression is:

$$\frac{113\,900}{(19.6 \times 15) + (31^2 - 19.6)} = 92 \text{ lb. per sq. in.}$$

The maximum moment due to wind is the same as for Case II, or 118 200 ft-lb.

The fiber stress due to bending is...	222 lb. per sq in.
The fiber stress in the concrete due to direct compression is.......	92 " " " "
The total compression in the concrete is	314 lb. per sq in.

The unsupported length of tower is fifty-two times the maximum width and seventy-seven times the average width. It would be of interest to know what "verified formula" would give the permissible strains per square inch for long reinforced concrete compression members.

A square cross-section, with four corner rods (*R, S, T*, and *U*), was chosen for the towers, as such an arrangement was more economical in steel than any other, each rod doing double duty. For instance, if the tower were strained about one axis, the rods, *R* and *S*, being in tension, if strained about another axis at right angles to the first, the rods, *S* and *T*, being in tension, the rod, *S*, would be doing double duty.

PLATE LXVII.
PAPERS, AM. SOC. C. E.
AUGUST, 1907.
KRELLWITZ ON
REINFORCED CONCRETE TOWERS.

Fig. 1.—Shears for Erecting Towers.

Fig. 2.—Reinforced Concrete Towers.

The tower at the right-angled turn of the line stood a remarkable test while changing the guys. On August 2d, 1906, it withstood the pull (tension in wires) parallel to the line without any guy to resist this pull. The maximum deflection at the top was about 2 ft. Not having the necessary apparatus at this time, the pull could not be ascertained. There were no visible cracks, nor was there any movement at the base. On another transmission line, however, a 59-ft. tower showed movement at the base, because the base was not large enough.

The base of each tower was constructed with an opening on one side so that the foot of the tower could not slide horizontally during erection. The finished base is a cube of concrete 10 ft. on each side, and having 8 ft. of the tower within it.

The moulds for the towers were inclined from the base upward, as shown by Plate LXVI, because the saving in erection more than offset the extra cost of excavating. While setting up the bottom sections on blocking, great care was taken to avoid unequal settlement. The side sections were set plumb, and braced properly to withstand the lateral pressures. The moulds were wet (except in freezing weather) before placing the concrete. Cores were set to wooden templets near the top for the holes required for bolting the cross-arms. Holes, 2 in. in diameter, were bored in the top side sections so that the bent ends of the foot steps would pass through when the moulds were removed.

The concrete for the towers was composed of 1 part of Portland cement and 5 parts of the very best gravel, with sand, of which 36% was "fine," having passed through a sieve of 0.2-in. mesh, and 64% was "coarse," being that which was retained in the sieve. The gravel, sand, and cement were first thrown together and turned over twice; water was supplied in pails, and the mixture was turned a sufficient number of times to produce a loose concrete of uniform color and consistency. Great care was taken in mixing the concrete and also in placing the steel and concrete.

At intervals of 20 in., foot steps were embedded in the upper part, and ladder rungs in the lower part, of each tower.

Two wooden shear legs, Fig. 1, Plate LXVII, with necessary steel back and side guys and steel hoisting tackle, were used in erecting the towers. Careful study was made during erection

as to the proper positions of the hitches, in order to avoid any excessive deflections which might be caused by concentrated pulls during erection.

The last tower was moulded on April 17th, 1906, and the sides of the mould were removed two days later. Its erection was commenced on May 25th, 1906, or 38 days after moulding; smaller towers, however, have been erected successfully 14 days after moulding.

It is believed that these towers are the highest monoliths in existence at the present time, and it may be interesting to state that during their erection no men were injured in any way.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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REINFORCED CONCRETE PIPE FOR CARRYING WATER UNDER PRESSURE.

By Chester Wason Smith, Assoc. M. Am. Soc. C. E.

To be Presented October 2d, 1907.

This paper describes the construction of about 6 000 ft. of reinforced concrete pipe intended to carry water under pressure; and also gives the results attained and some figures as to the cost. The work was in charge of the writer.

History and Conditions.

A prominent feature of the Salt River project, in process of construction in Arizona by the United States Reclamation Service, is a canal 19 miles long, having a capacity of 250 cu. ft. per sec. This canal is to furnish power to build the Roosevelt Dam, run the cement mill furnishing the cement therefor, and, later, pump water for additional irrigation in the vicinity of Phœnix.

At Livingston, about 6 miles below the canal intake, the canal crosses Pinto Creek, at that point nearly ½ mile wide, and about 25 ft. below the canal grade.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

The crossing of Cottonwood Cañon is 2½ miles above the Roosevelt Dam, which is at the lower end of the canal. The crossing is 250 ft. wide on the bottom and 75 ft. below the canal grade.

Pinto Creek has a water-shed of 190 sq. miles. At the canal crossing its grade is about 1%, and the material there is sand with a little gravel and small cobbles.

At the Cottonwood Crossing the cañon has a water-shed of about 4 sq. miles. The grade of the creek is about 4%, and the material is boulders and gravel.

Both creeks are dry nearly all the time, except for a small underflow; but they are subject to occasional large and sudden run-

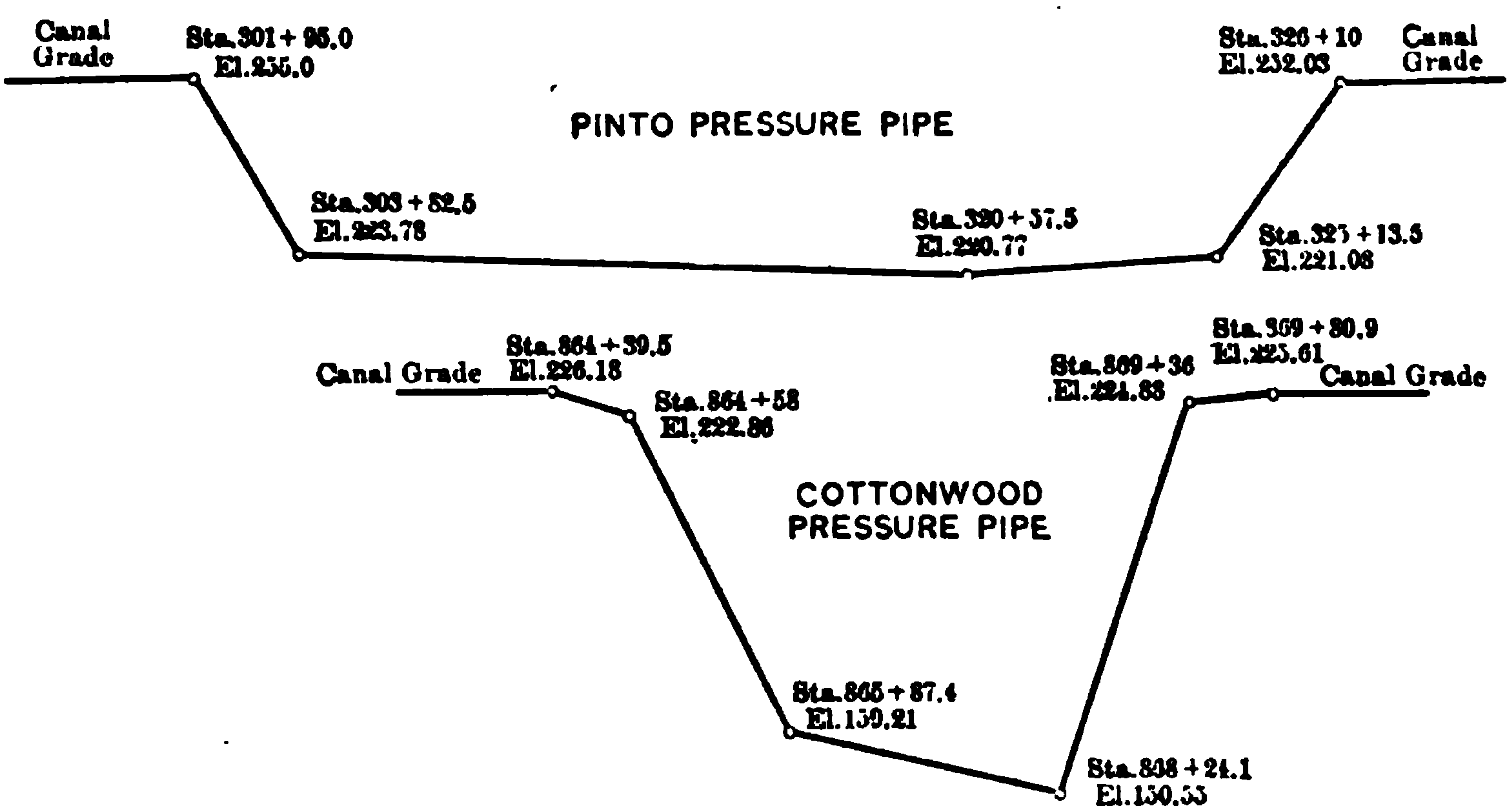


Fig. 1.

offs, characteristic of the flow from mountainous water-sheds which lack vegetation.

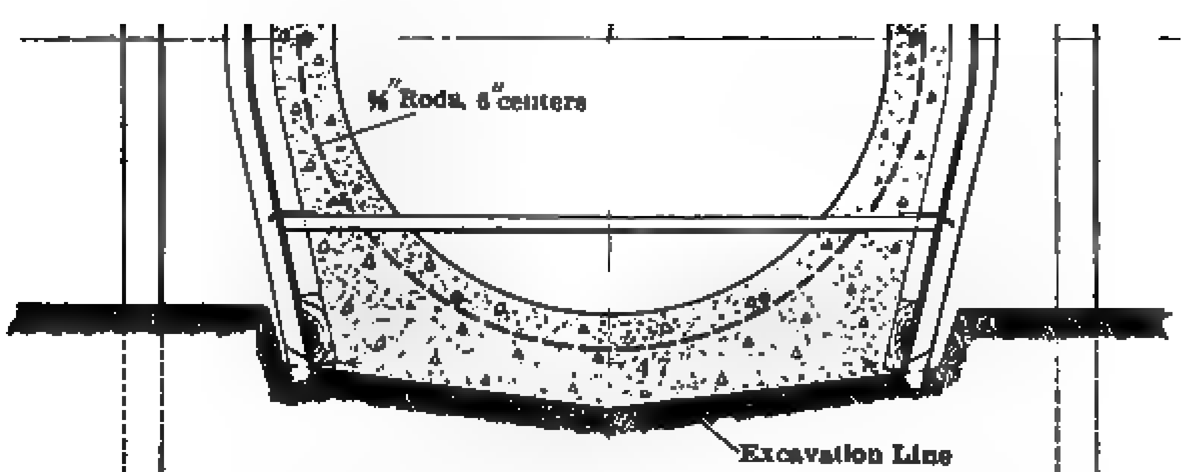
It was decided to make each crossing with two lines of reinforced concrete pipe, circular inside, and 5 ft. 3 in. in diameter, giving the Pinto Crossing an effective grade of 2.97 ft. in 2 415 ft., and the Cottonwood Crossing 0.57 ft. in 541.4 ft. The pipes are buried under the creek, their tops being from 2 to 5 ft. below its bed.

Fig. 1 shows the profiles of the pipes at each crossing, the water level in the canal at full capacity being 5½ ft. above the canal grades noted.

Fig. 2 is a cross-section of the Pinto pipe. The concrete in the Cottonwood pipe is 7 in. thick; there are ten longitudinal rods, and the spacing of the rings is 3 in. from center to center.

The reinforcement, longitudinal and transverse, consists of ⅝-in. steel rods, having an ultimate strength of 62 000 lb. and an elastic limit of 30 000 lb. per sq. in.

At Pinto Creek there was excellent sand and gravel at all points in the excavation; the water used in the concrete for the first line of pipe was pumped from the trench (the trench intercepting the



CROSS-SECTION OF PINTO PRESSURE PIPE

FIG. 2.

underflow of the creek), and the first pipe was tapped to furnish the water used in building the second one.

At Cottonwood the sand and gravel, and nearly all the water, were hauled about ½ mile from Salt River.

The concrete was composed of 1 part of Portland cement, 2½ parts of sand, and 4 parts of rather fine gravel, and was mixed by

hand, quite wet, on platforms of boards about 150 ft. apart along the trench.

The first length of 200 or 300 ft. of pipe was made in June, 1905, with cement purchased from the Portland Cement Company, of Denver, Colo. This was an average Portland cement. A progress of 120 ft. per 24 hours was easily attained with a comparatively raw gang.

Afterward, the cement used was the product of the mill installed and operated by the Reclamation Service to furnish cement for building the Roosevelt Dam.

During the summer and fall of 1905 nearly the entire output of this mill was required by contractors for various other work along the canal, and work on the pipe was frequently interrupted for considerable periods of time.

On account of lack of cement, also, on account of several floods, the completion of the first line of pipe across Pinto Creek was delayed until the middle of November, 1905.

As one line would carry all the water needed to furnish power for building the dam, and as power was required as soon as possible, the forms were then moved to Cottonwood, where the two lines were constructed. In March, 1906, the construction of the second line at Pinto was started, but, owing to various delays not connected with the construction, this line was not completed until about August 1st. Much of the time during the construction of both Pinto pipes the temperature was more than 100° fahr. The Cottonwood pipes were constructed entirely in winter, when the temperature was between 35 and 55 degrees.

The cement manufactured at Roosevelt, while excellent as regards strength and soundness, has been extremely slow setting. An average sample would test about as follows:

Fineness: 95% passed the 100-mesh sieve and 76% passed the 200-mesh.

Setting: initial, 4½ hours; final, 12 hours.

Tensile strength: neat, 7 days, 450 lb.; 28 days, 550 lb.; 3 months, 625 lb.; 1 part cement to 3 parts standard sand, 7 days, 100 lb.; 28 days, 200 lb.; 3 months, 260 lb.

A 6-in. concrete cube was made of the materials used in the pipe, except that the proportions were by weight, 1 cement, 2½ sand,

and 4½ gravel, mixed with about the same proportion of water. The batch from which the cube was made was composed of 1 200 g. of cement (of which only 64% passed the 200-mesh sieve), 3 000 g. of sand, 5 400 g. of gravel and 720 g. of water. This cube, after having set for 3 months in water, was crushed at 59 180 lb., or 1 644 lb. per sq. in. This rather low result was due partly to the coarseness of the cement, and partly to the fact that such a wet concrete was slow in attaining its strength.*

With such cement, and 70 lin. ft. of upper stationary plates, it was found that not more than 70 ft. of pipe could be made in 24 hours without getting into difficulties when the plates were removed, as patches of concrete would fall out or peel off with them. With cooler weather, the difficulties increased; accordingly, on the completion of the first line across Pinto Creek, the idea of continuous work was abandoned, and work on the Cottonwood lines and the remaining Pinto line was done with one 8-hour shift per day.

On the Cottonwood lines, built in December and January, it was found that only 24 ft. of pipe per day could be built, thus allowing 3 days for the concrete to harden before removing the plates.

The second Pinto line, constructed in warmer weather, was built at the rate of 40 ft. per day.

Movable Form.

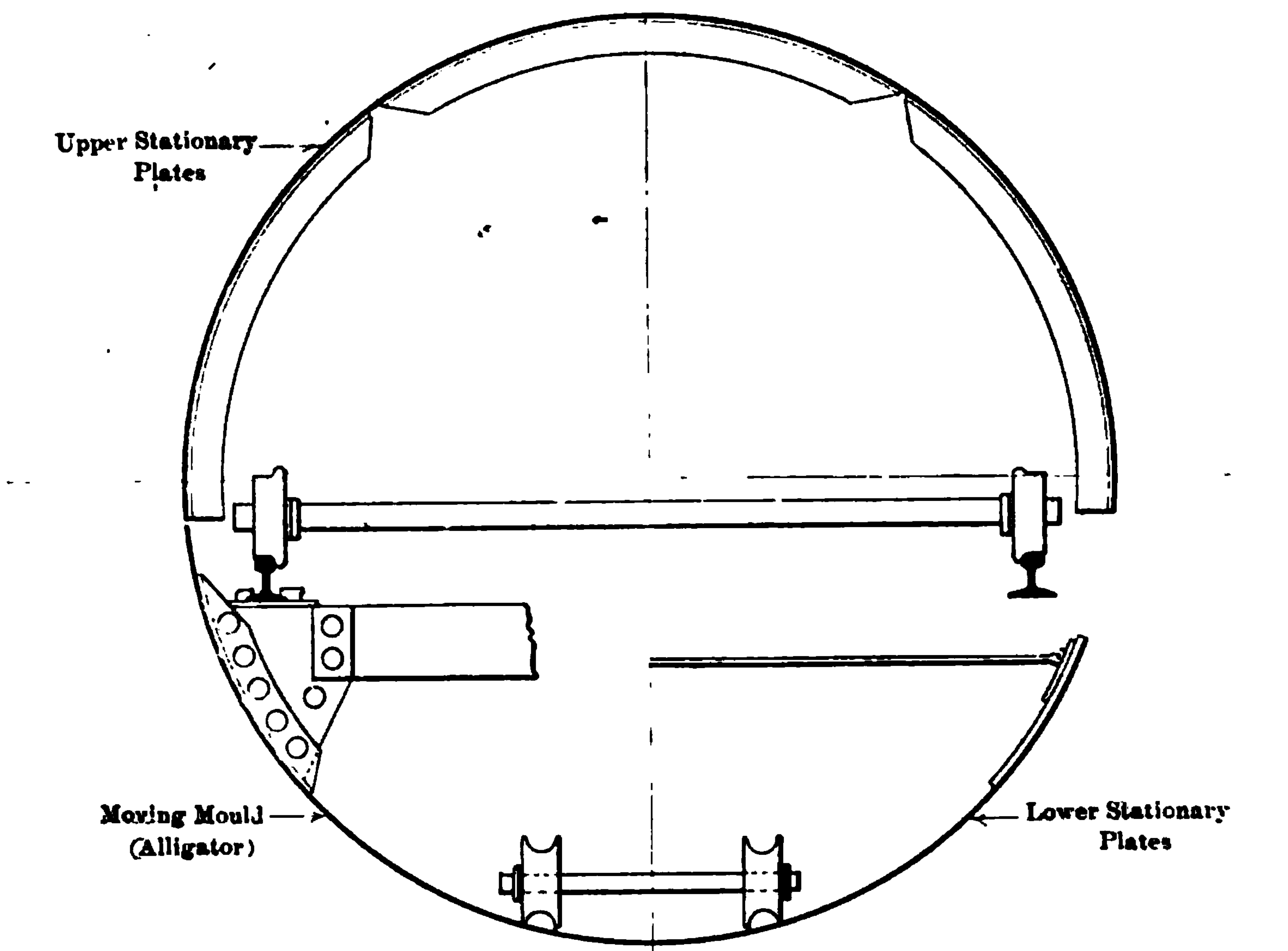
It was considered desirable to work continuously on the pipe, with three 8-hour shifts, in order to avoid, as far as possible, transverse joints, and consequent probable opening betwen the work of different days.

To facilitate continuous work, a movable form was designed and introduced on the work by F. Teichman, M. Am. Soc. C. E., Designing Engineer in the Reclamation Service.

Briefly described, the form, as shown in Figs. 3 and 4, and the photographs on Plate LXVIII, is as follows: A steel semi-cylinder, called "the alligator," forms the inside of the lower half of the pipe; this piece is pulled along by a cable from a horse-power whim

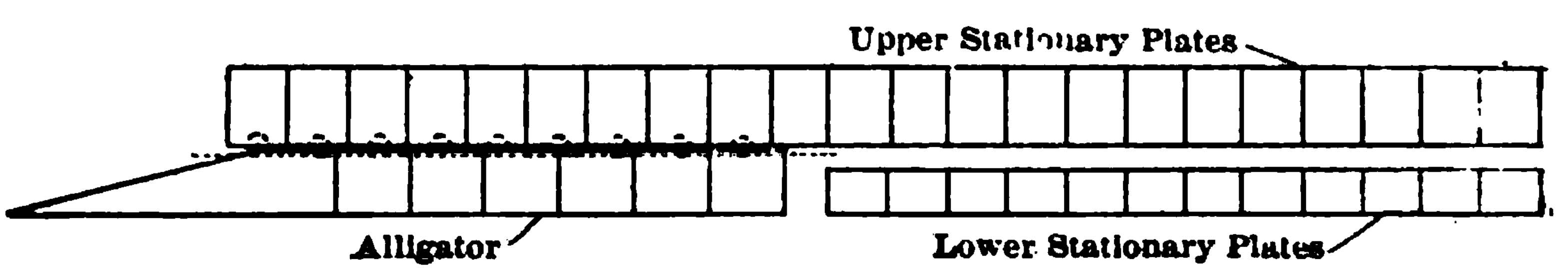
* Cubes since made from batches of concrete being put into the Roosevelt Dam have been crushed, at 3 months, as high as from 89 000 to 103 000 lb. per sq. in. This concrete was composed of 1 part of cement, 2½ parts of sand made by crushing dolomite limestone, and 4 parts of crushed sandstone, mixed to the same degree of wetness.

in the trench ahead. It is kept to line and grade by a steering apparatus, extending about 8 ft. in front of its nose, and either rolling or sliding on a light wooden track previously laid. The inner form for the upper half of the pipe consists of steel semi-



MOVABLE FORM
FOR BUILDING REINFORCED CONCRETE PRESSURE PIPE

Fig. 3.



PART OF MOVABLE FORM FOR BUILDING REINFORCED CONCRETE PRESSURE PIPE

Fig. 4.

cylinders in 2-ft. lengths, each in three pieces, that is, hinged at two points, to facilitate moving and erection.

These upper stationary plates are bolted together, end to end, making a continuous form, from the front end, where concrete is

FIG. 1.—THE "ALLIGATOR," USED IN BUILDING REINFORCED CONCRETE PRESSURE PIPE.

FIG. 2.—THE "ALLIGATOR," USED IN BUILDING REINFORCED CONCRETE PRESSURE PIPE.

going in, to the rear end, where the concrete has set sufficiently to permit their removal; they are supported by rollers on a track which is part of the alligator, the alligator thus rolling out from under the upper stationary plates. Immediately behind the alligator are introduced lower stationary plates in 2-ft. lengths, one plate being inserted as often as a length of 2 ft. of invert is exposed. On the withdrawal of the alligator, an upper stationary plate is thus supported by the plate ahead on the alligator and a plate behind on a lower plate, until the insertion of its lower plate. Upper and lower plates are removed at the rear end and sent ahead on a small truck hauled back and forth with a rope, on a track in the bottom of the lower plates and alligator.

The outside lagging was of 2½-in. lumber in narrow pieces, about 5½ ft. long, laid on the same slope as the nose of the alligator (1 in 4) between iron ribs hung from a wooden superstructure. This superstructure also carried the runways for wheeling out the concrete.

CONSTRUCTION.

The rings were bent to the desired circumference by a small bending machine. The ends were not upset or welded, but merely lapped about 15 in. and tied with baling wire; they were also wired at each crossing with each longitudinal rod, in order to hold them in place while the concrete was being put in.

The concrete was made with fine gravel, and mixed quite wet, in order to be worked into the narrow space between the reinforcement and the forms completely and easily. It was brought out in wheel-barrows on top of the superstructure and dumped wherever desired along the working face, that is, from the bottom of the pipe at the nose of the alligator, back on the 1 in 4 slope to the top of the pipe at the third or fourth upper stationary plate. One or two small chutes were found desirable in connection with the dumping.

Two men on each side, provided with small wooden paddles, churned the concrete to make certain that all voids were filled, and to prevent any nesting of the gravel. These men also introduced the outside lagging, that operation and the moving ahead of the alligator being regulated so that the working face was from

0 to 8 or 10 in. below the forms. On stopping work for the night, or if the continuous operation was interrupted for any reason, the blocking off was done at right angles to the axis of the pipe. This was done by stuffing sand bags between the inner and outer forms. This was more convenient than the use of a wooden stop, and afforded a rougher surface with which to bond when work was resumed.

The pipe was wet down on the outside for about a week after completion, and, as far as possible, the back-filling was kept up to the watering.

Some smoothing and pointing was necessary inside the pipe, and one or two brush coats of neat Portland-cement grout were applied; but no plaster coat was put on, nor was any water-proofing material used.

Difficulties.

It was difficult to overcome the tendency of the alligator to twist and travel off line or grade, and the steering apparatus was designed to prevent this, it not having been a part of the original form. It did much toward correcting the eccentricities in the travel of the alligator, but, at best, much depended upon constant watchfulness, and it was found necessary to stop work once in 8 or 10 days in order to level and straighten it out.

It is very doubtful if a uniform thickness could have been attained, even had an attempt been made to shift and adjust the outside forms and the reinforcement to correspond with the movements of the alligator. With this form, the minimum thickness will be at least 1½ in. less than the average thickness.

Considerable trouble was caused by the concrete peeling off with the upper stationary plates; particularly—in fact almost solely—with the middle segment of the plate. Large patches, often an inch or more in depth, would come off with the plate.

To overcome this, various schemes were tried; soft soap or crude oil was applied to the plates immeditely before covering them with concrete; particular care was taken to allow no spatterings of concrete to accumulate on the plate and dry out in advance of covering it with the mass of concrete; variations in the quantities of water in the concrete were also tried. Experience seemed to

FIG. 1.—THE CONSTRUCTION OF THE PINTO PRESSURE PIPE.

FIG. 2.—THE CONSTRUCTION OF THE COTTONWOOD PRESSURE PIPE.
(The inclines were built with wooden forms, concrete being run down in chutes from above.)

show that the only satisfactory remedy was to allow the concrete to set more thoroughly before removing the plates; if given sufficient time, a perfect surface was obtained. No special precautions were taken to guard against transverse joints between the work of different days, but, when an end was to be left for more than one day before resuming work, extra longitudinal rods were inserted, extending about 2 ft. into the work on each side of the joint.

RESULTS.

Transverse Joints.—On the first Pinto line, where there were few interruptions to continuous work, and where a portion of it was built in comparatively cool weather, there were very few transverse joints worthy of mention, and none requiring any treatment. On the two Cottonwood lines, built in the coldest weather, none has been observed.

On the second Pinto line, built entirely during the hottest weather, with about fifty interruptions to continuous work, and first filled in cold weather, it was to be expected that the transverse joints would be larger in number and size. At about forty of them there was a perceptible crack; of the forty cracks about twenty-five were $\frac{1}{16}$ in. or more in width, and were repaired, some of them before the pipe was first filled, and the remainder afterward. In general, they were more frequent and pronounced in one or two sections where the watering of the pipe was discontinued before the back-filling was done.

Longitudinal Cracks.—When the pipes were put in service, some longitudinal cracks, from $\frac{1}{16}$ to $\frac{3}{16}$ in. in width, developed (see leakage tests in Table 2), and at first various possible causes or contributary causes were assigned to them:

First, they were ascribed to the water hammer, which was considerable when the pipes were being filled.

Second, it was thought that the excavation of the trench for the second line of pipe (10 ft. from center to center of the first line) threw an eccentric load on the first pipe. This undoubtedly had an effect on the cracks in the first Pinto pipe, and, as soon as it was observed, the remainder of the second pipe was moved 10 ft. further away.

Third, the cracks being invariably in the top of the pipe, and within a few inches of the center, it was thought that possibly the laps in the reinforcing rings had been put in on that line, and that the rods, or some of them, had parted from the concrete. Enough evidence was at hand, however, to show that the laps had been properly staggered. If such had been the cause, a longitudinal crack developing in a few hours to 200 or 300 ft. long, would have resulted in the total failure of that portion of the pipe.

The true reason is undoubtedly as follows: The concrete shrank in the process of setting; this was resisted by the steel rings, thus producing a condition in which the steel was in compression and the concrete in tension. Therefore, on filling the pipe, the concrete took the entire load until it failed, and then the steel took the load.

That the cracks were invariably in the top of the pipe was probably due to the fact that the lower third of the pipe was in sand kept wet by the underflow; in effect, this lower part set under water, and the shrinkage was relatively small.

A careful inspection of the inside of the pipe showed that, wherever the crack occurred, the single large crack was the only one; and at points where there was no large crack, the upper two-thirds of the inside surface showed a network of very minute cracks.

These were from 1 to 4 or 5 in. apart, and generally so fine that they could have had but a very insignificant effect on the leakage, and, in fact, they were only detected by the presence of a minute line of the finest sediment which was deposited at the crack without passing through.

The writer is of the opinion that the minute cracks existed previous to the filling of the pipe, consequently, that at those places the steel carried the load immediately upon its application; however, there is no way to verify this. Repairs were made (on the inside of the pipe) in the following manner: each crack was cut out to a depth of about 2 in. and as narrow as possible, 1 in. of oakum was then caulked in tightly, and over that, the joint was pointed with stiff mortar. In addition, grout was run into the crack from the outside.

Several observations have been made for the purpose of determining the value of *n*, in Kutter's formula, and, while the en-

tire series contemplated has not been made, the observations on the Cottonwood pipes, thus far, show that $n = 0.012$, approximately.

In considering the results of the leakage tests, it should be borne in mind that Salt River carries considerable sediment. Observations at Roosevelt have shown that the quantity varies from a mere trace up to 4 or 5 per cent. Practically, the water is never without some sediment, but the maximum occurs only during the highest floods; the average would be between one-fourth and one-half of 1 per cent.

Between Roosevelt and the canal intake, considerable quantities of the sediment, at ordinary stages of the river, settle in the flat reaches, so that at the intake, while the maximum quantity of sediment is not more than at Roosevelt, the average is undoubtedly greater.

At several points along the canal there are mud boxes from which more or less sediment is occasionally sluiced, but the canal carries a larger percentage of sediment than the river, except when the latter is in flood.

COST.

The figures in Table 1, as to the cost of two sections of the second Pinto pipe, show the labor cost only, and do not include engineering, first cost of forms, cement, reinforcement, or grading.

TABLE 1.—COST OF PIPE.

	714 lin. ft. May, 1906.	1 009 lin. ft. July, 1906.
Laying track for steering alligator	$71.43	$48.98
Moving and erecting superstructure	299.94	358.44
Moving plates	202.50	252.44
Repairs to alligator	53.50	2.50
Bending rings	32.87	59.87
Placing reinforcement	126.94	138.13
Mixing and placing concrete	709.68	949.74
Watering	45.00	78.27
Pointing up and brush-coating inside	96.50	117.37
Blacksmith's work	30.00	25.00
Whim	28.87	23.75
Screening and hauling sand and gravel	183.18	300.00
Total	$1 880.41	$2 355.49
Barrels of cement used	466⅓	627
Number of days work	18	26
Labor cost per linear foot of pipe	$2.63	$2.33
Labor cost per cubic yard of concrete	5.93	5.25

A gang consisted of a foreman at $175 per month, a sub-foreman at $3.50 per day, and the following laborers at $2.50 per day: one bending the reinforcement rings; two placing the reinforcement; four taking down, moving and erecting the stationary plates; four placing the concrete and outside lagging; two wheeling concrete; six mixing concrete; one wheeling sand and gravel; one watering the finished pipe; four laying track for the steering apparatus, moving the superstructure and hangers, mixing boards, runways, etc.; one pointing and finishing inside the pipe; and one on the whim and doing miscellaneous work. The labor was principally Mexican, and only fairly efficient.

Results of Leakage Tests.

The leakage in the pipes was measured by observing the water level in them, all water being shut off. The head mentioned in the tables is the elevation of the water level above the lowest point in the pipe. The periods are consecutive in each case, that is, on January 25th the periods were during 2 consecutive hours, and on January 26th, during 6 consecutive hours, etc.

From February 26th to March 15th the pipe was in use a large part of the time. Various longitudinal cracks developed from time to time and were repaired. The next opportunity to measure leakage was from March 15th to 22d, after all the cracks had been repaired, since which time no more have appeared.

During the construction of the south line of the Pinto pipe, one lot of inferior cement, containing free lime, was received on the work, and a portion of it was used before being discovered. The result was a slower setting concrete, and at several places the upper stationary plates were removed too soon, allowing the concrete inside the reinforcement to settle and part from the outside.

Of these places, the worst one was repaired before the test of December 14th was made, but several minor ones, as well as most of the transverse joints, were not repaired until after that test.

TABLE 2.—Leakage Tests.—Pinto Pressure Pipe.—North Line.

This pipe was built between June and November, 1905, and first filled with water on January 25th, 1906.

Date.	Duration of test. Hours.	Duration of test. Minutes.	Leakage, in gallons.	Gallons per hour.	Average head.
Jan. 25, 1906	0	30	1 225	2 450	30.2 to 26.5
" 25, 1906	0	30	1 225	2 450	
" 25, 1906	0	30	1 130	2 260	
" 25, 1906	0	30	992	1 984	
Jan. 26, 1906	1	00	......	2 205	30.5 to 22.4
" 26, 1906	1	00	......	1 960	
" 26, 1906	1	00	......	1 837	
" 26, 1906	1	00	......	1 592	
" 26, 1906	1	00	......	1 102	
" 26, 1906	1	00	......	1 225	
(The pipe was full of water from January 26th to February 17th.)					
Feb. 17, 1906	1	00	......	300	21.5
Feb. 22, 1906	1	00	......	183	27.9
(On February 26th a longitudinal crack, 40 ft. long, developed.)					
Feb. 26, 1906	1	15	7 095	5 628	26.0 to 20.2
" 26, 1906	12	15	4 490	367	20.2 to 16.5
" 26, 1906	1	00	......	86	16.5
(This test shows the effect of a crack, and the effect of a small reduction of head.)					
Mar. 15, 1906, 8:15 A. M., to Mar. 22, 1906, 6:30 A. M.	2	30	375	150	26.9
	7	00	350	50	26.6
	14	30	1 650	114	26.3
	4	15	475	112	25.9
	5	00	420	84	25.6
	16	45	1 575	94	24.7
	6	45	460	68	23.9
	19	00	1 740	92	23.0
	6	15	375	60	22.1
	13	30	1 610	119	21.3
	11	30	715	62	20.4
	11	15	1 100	98	19.6
	13	00	730	56	18.9
	13	30	730	54	18.3
	11	00	460	42	17.8
	10	30	375	36	17.4
Dec. 19, 1906	16	00	9 898	618	30.5 to 20.9
	1	00		550	
	1	00		458	
	1	00		458	
	1	00		458	
Jan. 30-31, 1907	24	00	92	3.8	30.5
(This test shows the effect of a run of muddy water.)					

TABLE 2.—(*Continued*).—LEAKAGE TESTS.—PINTO PRESSURE PIPE.—SOUTH LINE.

Built March to August, 1906, and first filled on December 15th, 1906.

Date.	Duration of test. Hours.	Minutes.	Leakage, in gallons.	Gallons per hour.	Average head.
Dec. 15, 1906	1	00	18 320	18 320	30.5 to 15.5
	1	00	3 664	3 664	15.5 to 12.5
	1	00	489	489	12.5 to 11.6
	1	00	366	366	
	1	00	290	290	
Jan. 26, 1907	2	00	3 191	1 595	30.5 to 27.9
	2	00	3 100	1 550	27.9 to 25.4
	12	00	13 648	1 137	25.4 to 14.2
	2	00	641	320	14.2 to 13.7
Jan. 29-30, 1907	1	00	2 196	2 196	30.5 to 28.7
	1	00	2 107	2 107	28.7 to 27.0
	1	00	1 832	1 832	27.0 to 25.5
	1	00	1 832	1 832	25.5 to 24.0
	1	00	1 649	1 649	24.0 to 22.7
	1	00	1 465	1 465	22.7 to 21.5
	18	00	9 964	553	21.5 to 13.3

TABLE 2.—(*Continued*).—LEAKAGE TESTS.—COTTONWOOD PRESSURE PIPE.—SOUTH LINE.

Built between December 25th, 1905, and January 26th, 1906, and first filled on March 9th, 1906.

Date.	Duration of test. Hours.	Minutes.	Leakage, in gallons.	Gallons per hour.	Average head.
Mar. 9, 1906	0	30	535	1 070	84.4 to 84.3
" 9, 1906	2	30	1 452	580	
" 9, 1906	1	00	......	478	
" 9, 1906	1	00	......	448	
" 9, 1906	1	00	......	370	
Mar. 10, 1906	0	30	1 475	2 950	49.0
Mar. 27, 1906	2	30	38 100	15 200	74 to 18.
Sept. 22, 1906	7	00	0	0	74

The south line was the first one constructed at Cottonwood. Some time in April the pipe failed by blowing out a hole about 4 ft. square in its top. This was at the point where the first roof plates were removed, and would indicate that they were removed too soon, allowing the concrete inside the reinforcement to settle a little and part from the reinforcement and the outside concrete. The hole was cut out to solid work, and patched.

TABLE 2.—(*Continued*).—LEAKAGE TESTS.—COTTONWOOD PIPE.—NORTH LINE.

Built January 8th to 20th, and first filled on March 9th, 1906.

Date.	Duration of test. Hours.	Minutes.	Leakage, in gallons.	Gallons per hour.	Average head.
Mar. 9, 1906	0	40	167	251	24.0 to 22.5
	2	30	591	237	
	1	00	......	177	
	1	00	......	121	
	1	00	......	98	
Mar. 10, 1906	0	30	3 540	7 080	69.0
	2	30	12 500	5 000	60.0
(8-ft. longitudinal crack opened.)					
Mar. 23, 1906	2	15	4 525	2 010	60
	0	30	1 048	2 097	78
Mar. 27, 1906	2	20	9 000	3 860	74.0 to 60.7
Mar. 28, 1906	5	45	......	1 170	73 to 68
Mar. 29, 1906	18	45	......	800	58
Apr. 16-17, 1906	26	00	......	39	74
May 24-26, 1906	55	00	863	16	74
May 28-29, 1906	48	00	000	00	74
Sept. 22, 1906	24	00	000	00	74

Between March 10th and 27th various short longitudinal cracks developed and were repaired. The pipe was in service intermittently. Since the end of March the pipe has been almost constantly in service.

CONCLUSIONS.

The very slow setting cement used on this work rendered it impracticable to work continuously on account of the excessive number of stationary plates which would have been required.

With a cement setting in average time, the continuous process would certainly be practicable and advisable; and a machine similar to the one described herein, or designed to accomplish similar results, would probably be the best solution of the question of forms.

The necessity of continuous work may be said to vary with the temperature at which the pipe is constructed; at low temperatures it would be almost a matter of indifference; even at high temperatures it is probable that continuous work would not be absolutely necessary, because a method of making connections which would result in a nearly water-proof joint could probably be devised.

There are many engineering works, in process of construction, or projected, for conveying water under pressure, where similar reinforced concrete pipe could be used, and would be, were engineers satisfied as to its first cost, durability and reliability.

The question may be asked, what is the maximum head for which this kind of construction could be used? The precedent for such construction, as well as the literature on the subject, are both believed to be quite meager, though the writer has had little opportunity for searching engineering literature. Attention might be called to a paper* by J. H. Quinton, M. Am. Soc. C. E., entitled "Experiments on Steel Concrete Pipes on a Working Scale."

The excessive amounts of leakage reported in that paper would seem to have been due to the use of a dry mixture, and the writer would take decided exception to the conclusion (expressed on page 55), that "reliance for impermeability must be placed on the plastering rather than on the material of the pipe." Reliance should be placed upon a wet mixture of the material of the pipe.

There is no doubt that the first cost would be less than for either cast-iron or riveted-steel pipe, and would be little if any in excess of wood-stave pipe.

As regards durability, the question is as to the relative durability of the metal in the various kinds of pipe, disregarding for the moment the life of the wood staves.

The reinforced concrete pipe should be far less likely to be destroyed by electrolytic action than either cast-iron or steel pipe. The reinforcement receives a coating of cement which stays with it when the surrounding concrete is cracked or broken away, and the question becomes one of the relative efficacy of the cement coating on one hand, and the asphalt coating of the metal pipe on the other, remembering that the cement coating is absolutely protected against abrasion, and also enclosed in a manner which renders inspection difficult and incomplete.

It may be observed here that the metal in the reinforced concrete pipe possesses the same advantage over the metal in the riveted-steel pipe which has been advanced in favor of the bands on wood-stave pipe; *i. e.*, of form, being a rod with a diameter considerably greater than the thickness of the riveted-steel pipe. In

* Water Supply and Irrigation Paper No. 143 of the United States Geological Survey.

other words, given a certain quantity of steel per linear foot of pipe (enough to carry the load), the most durable form would be that with the least amount of exposed surface.

The problem of inspection might be solved by cutting into the steel occasionally at suspected points, such as at some crack or leak. The reinforcement in the concrete pipe should have a much longer life than the bands on the wood-stave pipe, though, on the other hand, the latter can be readily inspected and renewed.

Of course, as to the relative permanence of wood and concrete, there can be no question, even admitting the claims of the most ardent wood-stave advocates.

The reliability, or safety against sudden failure under a high pressure, seems to the writer to be simply a matter of correct design (to be determined, doubtless, by experiment), and the character of the inspection of the materials and construction. It is not necessary to state that the inspection should be absolutely first-class. It would seem that in correct design the relative quantities of concrete and steel should be such that the concrete in shrinking cannot compress the steel, but will crack; then, with nearly perfect adhesion of the two, there should be many cracks, but so minute that they will readily silt up.

Whether the concrete cracked at few places or many would depend upon the quality of the concrete, the relative quantities of concrete and steel, and the degree of perfection of the adhesion. In this there is a field for experiment, in order to determine the strength of adhesion of concrete and steel, the best form of reinforcing rod, and the amount of shrinkage during the setting of various mixtures of concrete.

It will undoubtedly be found that there is a minimum advisable spacing for the reinforcing rings, on account of their tendency to form a plane of cleavage and thus separate the concrete into an inner and an outer shell; also to insure the complete filling of the entire space with the concrete. For a large quantity of steel in the section, the arrangement might be in the form of two or more rows of rings staggered.

This paper is presented, not as pretending to solve the problem, but with the hope that the governing considerations have been stated correctly, and that the suggestions will be of some value.

In conclusion, the writer wishes to acknowledge valuable assistance derived, during the construction of the pipe and the repair of the cracks, from a free discussion of the various problems with Louis C. Hill, M. Am. Soc. C. E., Supervising Engineer; F. Teichman, M. Am. Soc. C. E., Designing Engineer, and Mr. A. L. Harris, Assistant Engineer; also the exceptionally conscientious work of Mr. A. P. Cox, Foreman.

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PAPERS AND DISCUSSIONS.

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THE BRACING OF TRENCHES AND TUNNELS, WITH PRACTICAL FORMULAS FOR EARTH PRESSURES.

By J. C. Meem, M. Am. Soc. C. E.

To be Presented October 16th, 1907.

In this paper the sheathing and bracing of trenches and tunnels in dry and water-bearing materials, will be treated under the general subject of bracing. In order that there may be no misunderstanding, the term "sheeting" will be used for that class of sheathing which is set in or driven coincidentally with the excavation. That class of sheathing which is driven ahead of the excavation, or beyond its final limits, will be referred to as "sheet-piling."

Ordinarily, sheeting is set in or driven by hand-mauls, whereas sheet-piling is driven by pile-drivers. In order to make the descriptions as clear as possible, reference is made to Figs. 1 to 4, which show in a general way the different types of sheeting and bracing.

Fig. 1 shows a general type of open trench sheeted with two sets of, or "double," sheeting.

Fig. 2 shows a detail of the principal features of the sheeting

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

(ordinarily 2 or 3-in. spruce or Virginia pine), the ranger wit' engaging brace, and the cleats and lugs for holding them in pos

Fig. 3 shows a general type of excavation in a coffer-sheeted with 12 by 12-in. tongued and grooved sheet-piling, dr between guide-wales, and penetrating beyond the limits of the cavation, but not sufficiently far to do away with the necessity bracing. These guide-wales are usually bolted to ordinary p driven ahead of the sheet-piling and removed as it approaches th

Fig 4 shows the cross-section of a general type of hand-driv tunnel or drift. The cap, legs, and sill are clearly defined, with spreader under the cap, the rear ends of the front lagging restiı on the cap, and the front ends of the rear lagging superimpos above everything, with the waling pieces and fillers and wedg between. The same terms hold good for the sides. The filler shown at the right of the sketch just over the cap are put i temporarily to hold the waling piece in position until the lagging or poling boards can be driven.

Referring now to the general question of earth pressure, in connection with its action on sheeting and bracing, the writer believes that this subject has never been developed so as to reconcile the theoretical with the practical conditions. It will be his endeavor to develop a practical basis in connection with which it will be possible at all times to effect an approximate reconciliation between the actual conditions of stability of earth and the theoretical formulas or resultants arising therefrom.

In all his experience, the writer has used the diagram, Fig. 5, for calculations of earth pressure, whether applied to retaining walls or to sheeting and bracing.

If $B\ C$ be the line of the sheeting, and $D\ C$ the natural slope of the earth, b being the angle of repose, then the mass of earth causing pressure against the line, $B\ C$, is contained within the triangle, $D\ B\ C$.

The weight of the earth in this triangle rests on $D\ C$, and its thrust is transmitted to $B\ C$, not through the toe of each layer at the foot of its slope line, but by the arching effect of this earth between the lines, $B\ C$ and $D\ C$.

For purposes of calculation, it is probably not far from correct to assume that a line, $A\ C$, bisecting this triangle, $D\ C\ B$, measures with $B\ C$ an area equivalent to the weight transmitted as thrust

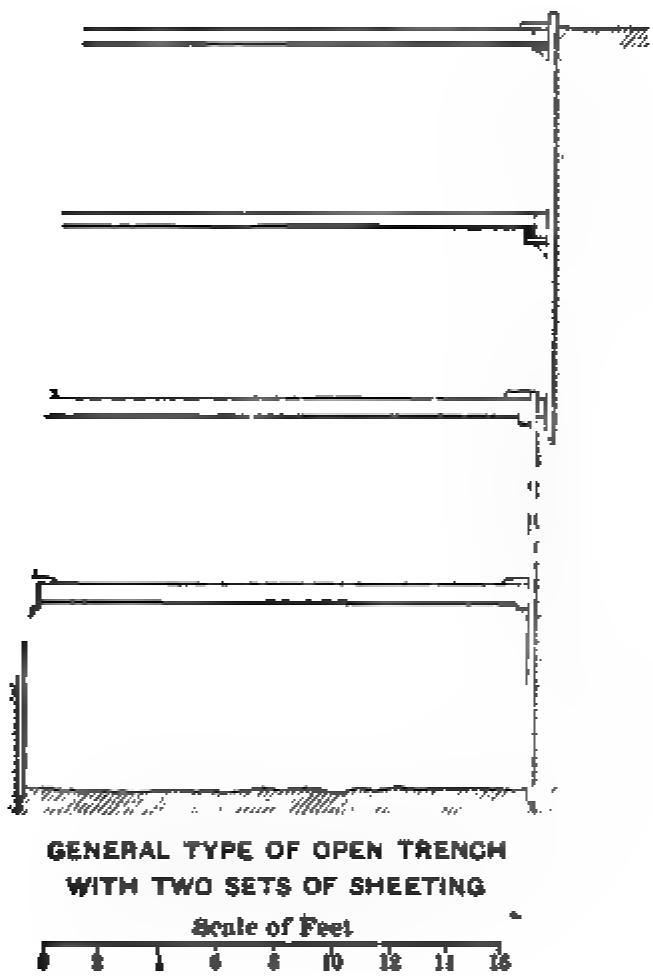


FIG. 1

FIG. 2.

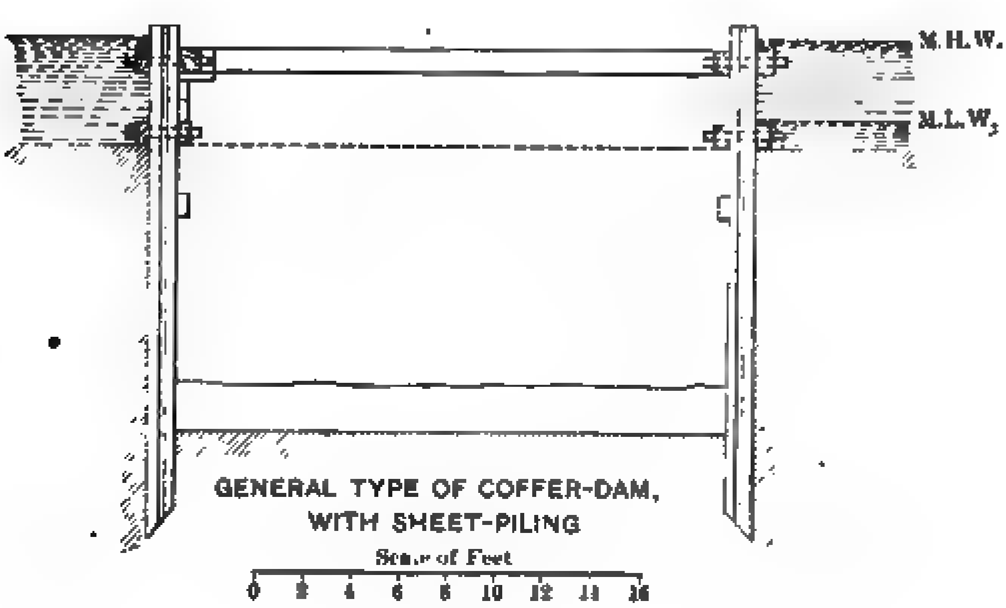


FIG. 3.

against this line, $B\ C$. Also, it is true that the center of pressure against $B\ C$ is where a perpendicular from the center of gravity of the triangle, $A\ C\ B$, meets this line.

The writer is fully aware that in making this assumption he is

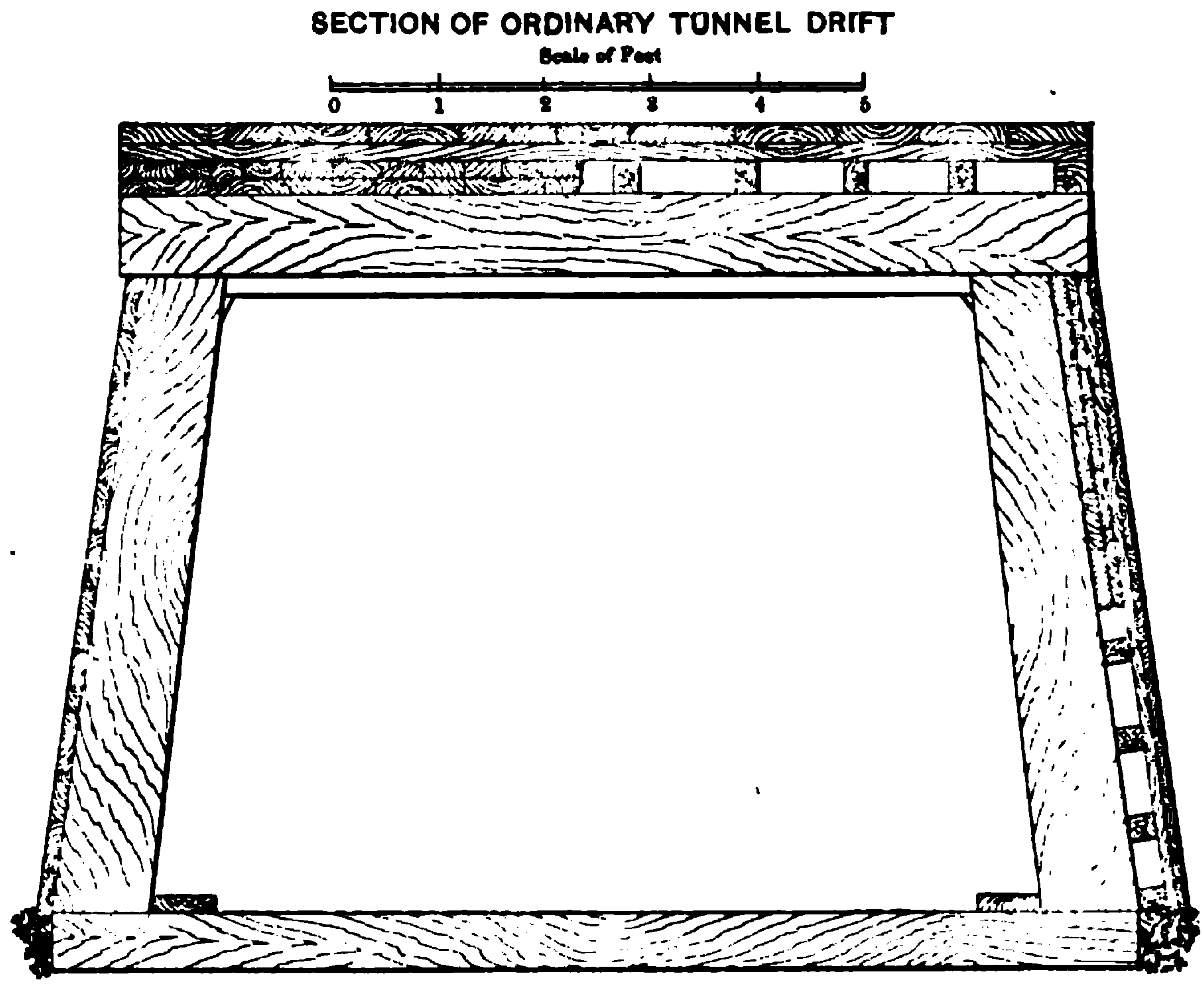


FIG. 4.

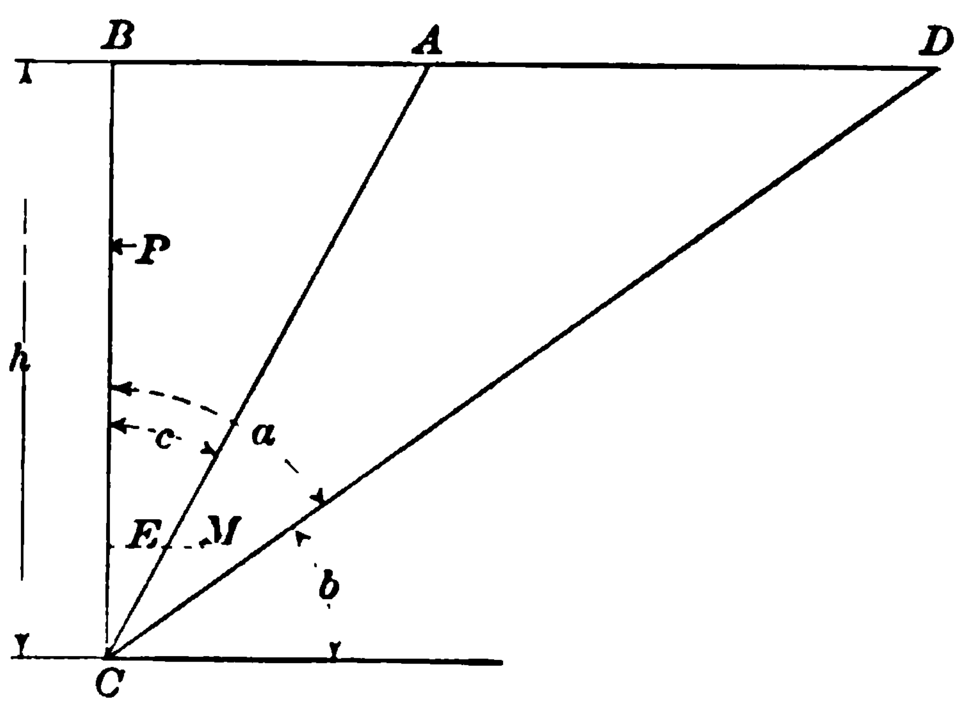


FIG. 5.

going contrary to the general theory, which assumes that earth pressure acts along the line of rupture and parallel with that line, and is therefore greatest at the toe, but he wishes to state that this theory is not borne out in actual practice, and that all closely-sheeted,

well-braced trenches invariably show a heavier pressure at the top than at the bottom. Any attempt to assume a theoretical condition which is contrary to this fact must be of little value to engineers in making practical calculations. The writer is aware that many retaining walls have been built from designs based on this theory; and he may state parenthetically that it makes little difference, practically, which form of reasoning is applied to retaining walls. It does, however, make a vast difference which form of reasoning is applied to a braced trench, or to a concrete wall reinforced horizontally; and, while the writer does not wish to contradict this theory, if based entirely on a theoretical condition of frictionless material, he does wish to advise against its use in ordinary practice. In other words, if it be assumed that *D C* is a solid plane, and that the triangle, *D C B,* is filled entirely with particles which are absolutely without friction, and therefore the weight of one upon the other transmits accumulatively the weight of all entirely and directly to the bottom, then the truth of the theory noted above cannot be controverted. The writer is convinced, however, that such a condition does not exist, and that earth pressures and aqueous pressures are not similar; for, in dealing with ordinary materials, it is impossible to proceed with any practical calculations without taking into account the frictional resistance of these materials and their arching effects, which render it virtually impossible to consider their action as in any way allied to hydrostatic action. For instance, the writer has repeatedly observed (where trenches have been sheeted from *B* to *E,* Fig. 5, and the excavation has been continued below *E* without sheeting), undercutting excavations which have been made (in loams, clays, or moist sands) back along the line, *E M,* by the usa of light poling-boards driven in under the toe of the sheeting at *E,* without disturbing the stability of the mass above. He is satisfied that if this sheeting had been so poorly put in as to cause the stability of the mass to be disturbed, it would have manifested itself by the continual dropping of masses of material from above, rather than as a constant pressure, as would have been the case had the material been full of water or absolutely frictionless. And, if any small holes should be left between these poling-boards in absolutely dry sand, it would "bleed" in through these orifices just as the sand

runs into an hour-glass, until the hole had gone to the top of the excavation, but at no time would there be observed any continuous pressure which could be defined in any way as equal to the entire weight of the sand from the bottom to the top over the unsheeted area. It may be, and the writer has frequently observed also, that the lower part of a trench may be left unsheeted, as from *E* to *C*, and for a considerable distance longitudinally in clays and moist sands, without disturbing the stability of the face, *E C*, and yet more or less heavy pressure may be observed in the bracing above. This can only be explained on the theory of the arching effect of the material above, one buttress of the arch being *B E*, and the other *D C*. If this be correct, there can be no doubt of the action being wedge-like, with the center of pressure opposite the center of gravity. Any engineer who has had to do with excavations must be aware of the fact that pressures are frequently developed in the top braces and rangers while men are excavating with impunity beyond the limits of the sheeting at the bottom of the trench. It is possible, also, at any time to cut or remove the bottom sheeting (except in dry sand) for a considerable percentage of the vertical distance from the bottom, and for indefinite lengths, without interfering with the stability of the bank above, provided the sheeting is removed without jarring. Any practical man, however, will admit that it would be suicidal to remove any one of the braces near the top of the excavation, particularly after the ground had stood for any considerable time.

The practical application of the foregoing will now be shown, and the formula be demonstrated.

If b (in Fig. 5) = the angle of repose,

$a = 90° - b$, and

$c = \frac{a}{2}$,

h = height = $B\ C$,

w = weight of 1 cu. ft. of earth.

Then, the area of $A\ C\ B = h \times \frac{h \tan. c}{2}$, and the weight of the mass of earth causing pressure on $B\ C = \frac{w\ h^2 \tan. c}{2}$.

The resultant pressure of this mass would occur at two-thirds of the height, or at *P*, in Fig. 5.

In the case of a well-sheeted and braced bank, there would be no overturning moment, but there would be a thrust, represented by the general tendency of the triangle, $A\ B\ C$, to slide along the line, $A\ C$, and therefore move out and exert pressure in a horizontal direction.

To understand this more clearly, it might be well to assume (in Fig. 6) that the lines, $D\ C\ A$ and $D\ C\ B$, are blocks of ice which are held in place along the line, $B\ C$, by their weight impinging on this line, and on the line, $A\ C$, by a rigid strut bearing against that line at P. If the pressure at P be slightly released, the whole triangle, $A\ B\ C$, will assume a new position, $A_1\ B_1\ C_2$. If, again, $A\ D\ C$ be taken as a solid wedge bearing against a solid block, $D\ C$, and the wedge be forced down, then, in

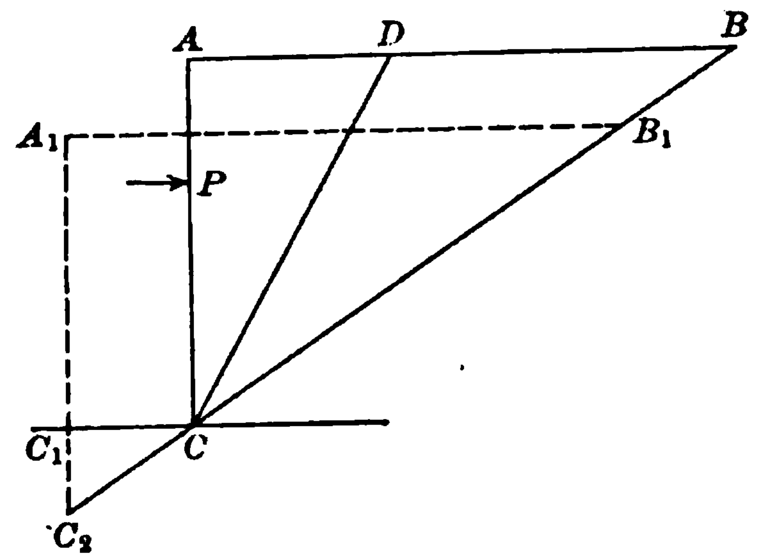


FIG. 6.

order that it may be resisted most effectually at any one point, this resistance should be placed at P. Or, in a word, the writer believes that the action of earth pressure in properly braced trenches is more closely allied to that of a coherent solid than to that of an aqueous or frictionless mass.

If, now, these pressures be applied to an ordinary sheeted and braced trench of an assumed depth of 40 ft., and if the weight of earth be assumed at 90 lb. per cu. ft., the pressures obtained at the braces shown in Fig. 7 will correspond with the figures in the rectangles opposite these braces. The maximum pressure on any portion of a trench sheeted in this manner would occur at the second brace, where the pressure for the assumed case would eventually be 8 640 lb. per ft. If these braces are spaced 10 ft. apart, it would be necessary to use a 12 by 12-in. yellow pine ranger to resist this

pressure (with a factor of safety of 3), and the third, fourth and other rangers would be of correspondingly smaller cross-sectional area. It is rarely found in practice, however, that it is necessary to use a ranger as heavy as that required by the theoretical conditions here assumed, for, if the trench be well-sheeted and braced, the horizontal arching effect of the material will come into play,

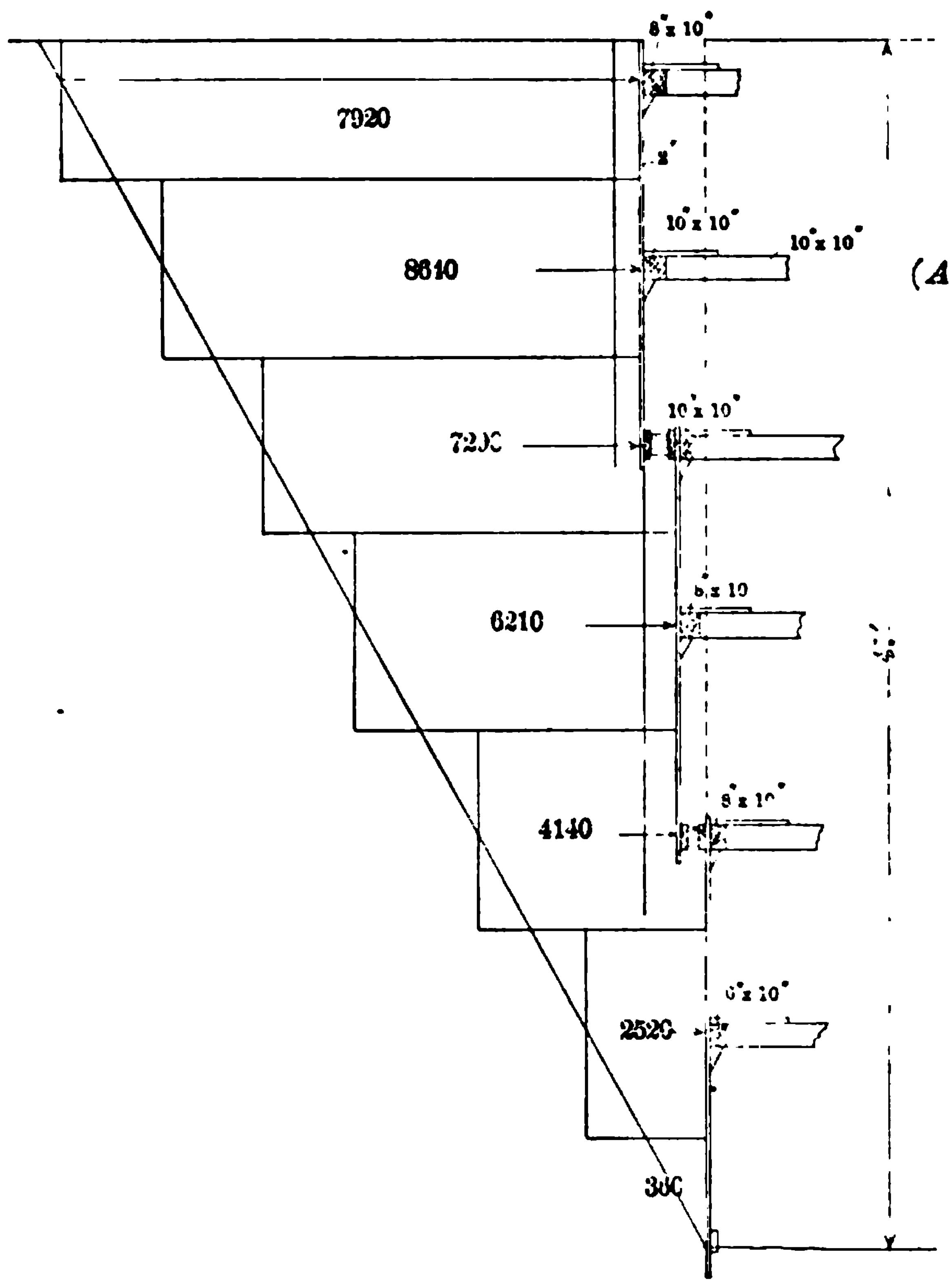


FIG. 7.

and will transmit itself from brace to brace and allow the use of a lighter ranger. It is also customary, within the limits of good practice, to use much lighter sheeting than that which would be theoretically required to maintain or resist this pressure, as the braces and rangers, if properly placed, take up the pressures and allow the arching effect previously noted to perform its work.

In Fig. 7 are noted the sizes and kinds of sheeting and bracing which would be used in ordinary practice in a trench 40 ft. in depth, and, while not recommended as theoretically strong enough, they give satisfactory results in ordinary ground where the trench does not have to stand too long, and always assuming that the bracing is properly put in originally. The top brace here shown is 8 by 10-in., the second and third are 10 by 10-in., the fourth and fifth are 8 by 10-in., and the bottom one may be a 6 by 10-in. These sizes apply to a good grade of Virginia or short-leaf yellow pine. Ordinarily, the toe of the sheeting is driven 1 ft. or more into the bottom material, which holds it in place without the necessity for bracing this toe. The braces sustaining the rangers (except in very narrow excavations) should be fully as large as the rangers themselves, as any tendency to distortion might be fatal to the stability of the banks; and, if the trench is very wide, longitudinal spreaders should be placed between the braces at sufficiently frequent intervals to prevent the possibility of distortion. These spreaders obviate the necessity of using heavier braces.

The writer believes that there is a limit of depth beyond which it is not possible to brace a trench against the pressures which would be developed, and he believes that this limit could be defined by a simple practical calculation, depending, of course, upon the nature of the soil through which the trench was dug. For example, if a trench be sunk 20 ft. and stopped, the pressure developed at the 15-ft. level will not be excessive, whereas if it be continued to 60 ft. the bracing will have to be heavily reinforced at the same 15-ft. level; and, if the trench be carried down to an indefinite depth, no bracing would eventually be able to withstand the pressures at this same point, owing to what may here be described in a homely way as the "topheaviness" of the bank. Anyone who has had to do with deep trenches or tunnels, however, must realize that an exposed face of earth is under no more pressure at the bottom of the deepest trench or tunnel than it is at the bottom of a shallow one.

Reference is here made to Fig. 1, Plate LXX, which shows the bottom of a lined tunnel (at a depth of some 70 ft.) which had been driven with an ordinary shield, and from the bottom of which several cast-iron plates had been removed. The places from which

the plates were removed show an exposed face of moist sand, and it is clearly evident that it is in as quiescent and undisturbed a state as though the exposure had been made only a few feet from the surface. The rod shown in the photograph is vertical.

The danger in sheeting a trench arises mainly from three causes:

a.—In driving the sheeting carelessly and allowing slips to occur behind it; or, in the case of clayey soils, not properly guarding against voids which may occur behind the sheeting. The natural tendency of earth eventually to fill these voids causes slips, which develop not only the full pressures theoretically provided for, but frequently, by reason of the shock incidental to the velocity of slip, cause increased pressures to impinge against the sheeting and incidental bracing.

b.—In not fully tightening the braces by the use of wedges driven practically to refusal; and

c.—Because strata of quicksand may be uncovered in ordinary soil, thereby developing hydrostatic and unbalanced pressures on the sheeting and causing stresses not properly provided for.

The next consideration is that of bracing and sheeting and its relation to earth pressures in subaqueous or other soils so saturated as to be under hydrostatic pressure.

There appears to be no controversy as to the generally accepted theory and formula in connection herewith, and they will merely be discussed in order to preserve the continuity of this paper.

Fig. 8 shows graphically the theory of hydrostatic pressure, which assumes that it is cumulative vertically and constant in the horizontal planes, and that the center of pressure is always at a point one-third above the base. If, now, it be assumed that *A B* is sheet-piling which has been driven through water and into the ground at *C*, penetrating sufficiently far beyond *O* to cause it to act as a cantilever, then the moment tending to overturn this sheet-piling is as follows:

If $h =$ the height (in Fig. 8),

$w =$ the weight of 1 cu. ft. of water,

and, if the width of each pile be 1 ft., then

$$h \times \frac{h}{2} \times w = \frac{w\,h^2}{2} = \text{the weight bearing against each pile,}$$

and $$\frac{w\,h^3}{6} = \text{the moment tending to overturn each pile.}$$

FIG. 1.—SAND IN REPOSE AT SIDE AND BOTTOM OF TUNNEL.

FIG. 2.—PIT, 6 FT. SQUARE, LINED WITH HORIZONTAL SHEETING.

If a brace be placed at the point, H_1, the piling becomes a beam with the load distributed over the whole area, the resultant being at P. The writer is not convinced that it is necessary to consider the full hydrostatic pressure on that portion of the pile represented in Fig. 8 by $C\ O$. He believes that the frictional resistance of the earth here prevents this full hydrostatic pressure from being developed, but he would not be willing to neglect this in making practical calculations, and therefore he believes it should always be taken at its full value. The same reasoning applies to subaqueous tunnels, or to any subaqueous structure in soil sufficiently permeable to admit water in reasonably large quantities.

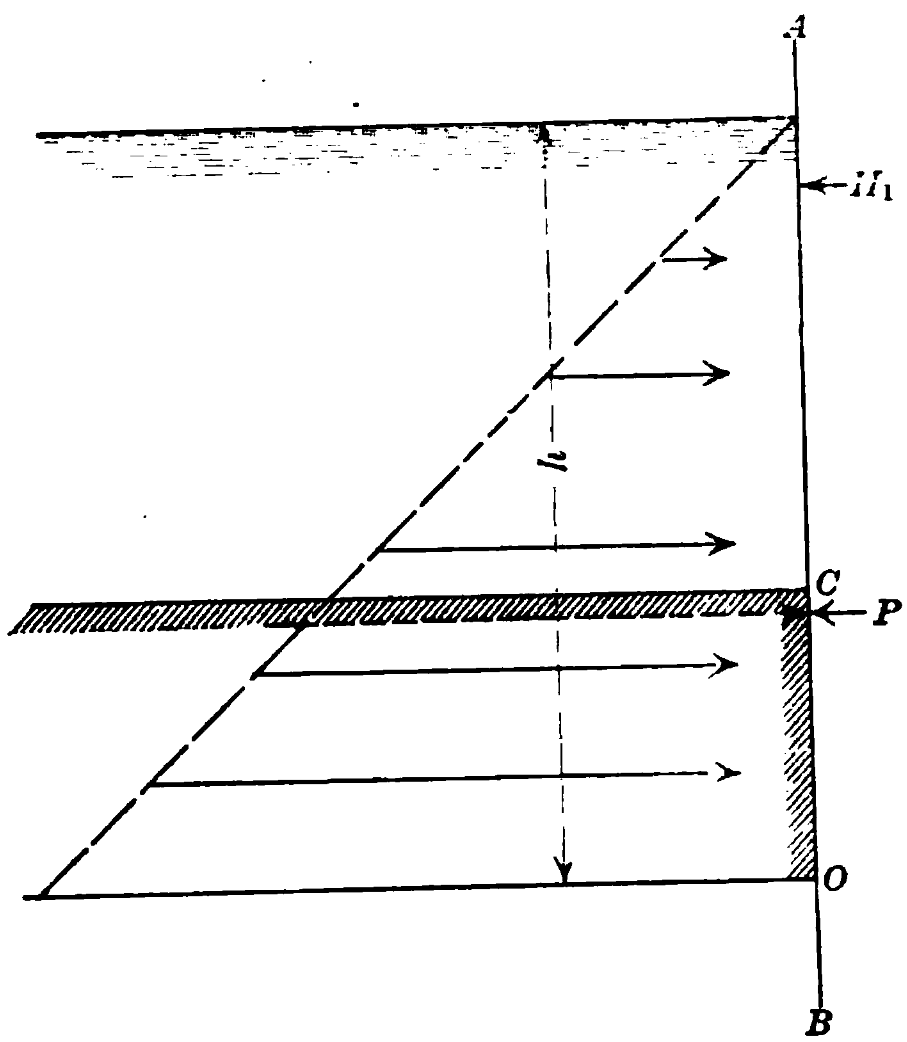


FIG. 8.

The next question to be taken up will be earth pressures on tunnels or subterranean structures, where it is necessary to consider the other side of the pressure areas noted in the development of the formulas for pressures in open trenches.

Referring to Fig. 9, if it be assumed that $B\ D\ J\ I$ is a tunnel (the area of which will be taken as a square, in order to simplify the assumptions), and that $H\ D$ or $D\ F$ is the natural slope of the earth above this tunnel, then:

$a =$ the angle of repose,

$b =$ the complement of the angle of repose, and

$c = \frac{b}{2}$.

As a first assumption, it is unquestioned, of course, that all earth contained in the triangle, *B C D,* necessarily presses directly on the roof of the tunnel. And if the assumptions made at the beginning of this paper are true for open trenches, then it is also true that all the earth contained in the triangle, *A C D,* bears directly upon the line, *C D,* and therefore all this weight likewise is transmitted to the tunnel and all the pressure of the earth in the triangle, *A D L,* goes to the line, *L D,* arching itself somewhere below the triangle, *B A D,* in a curve approximating the line, *B S D,* so that, in a well-braced tunnel, the only pressure on

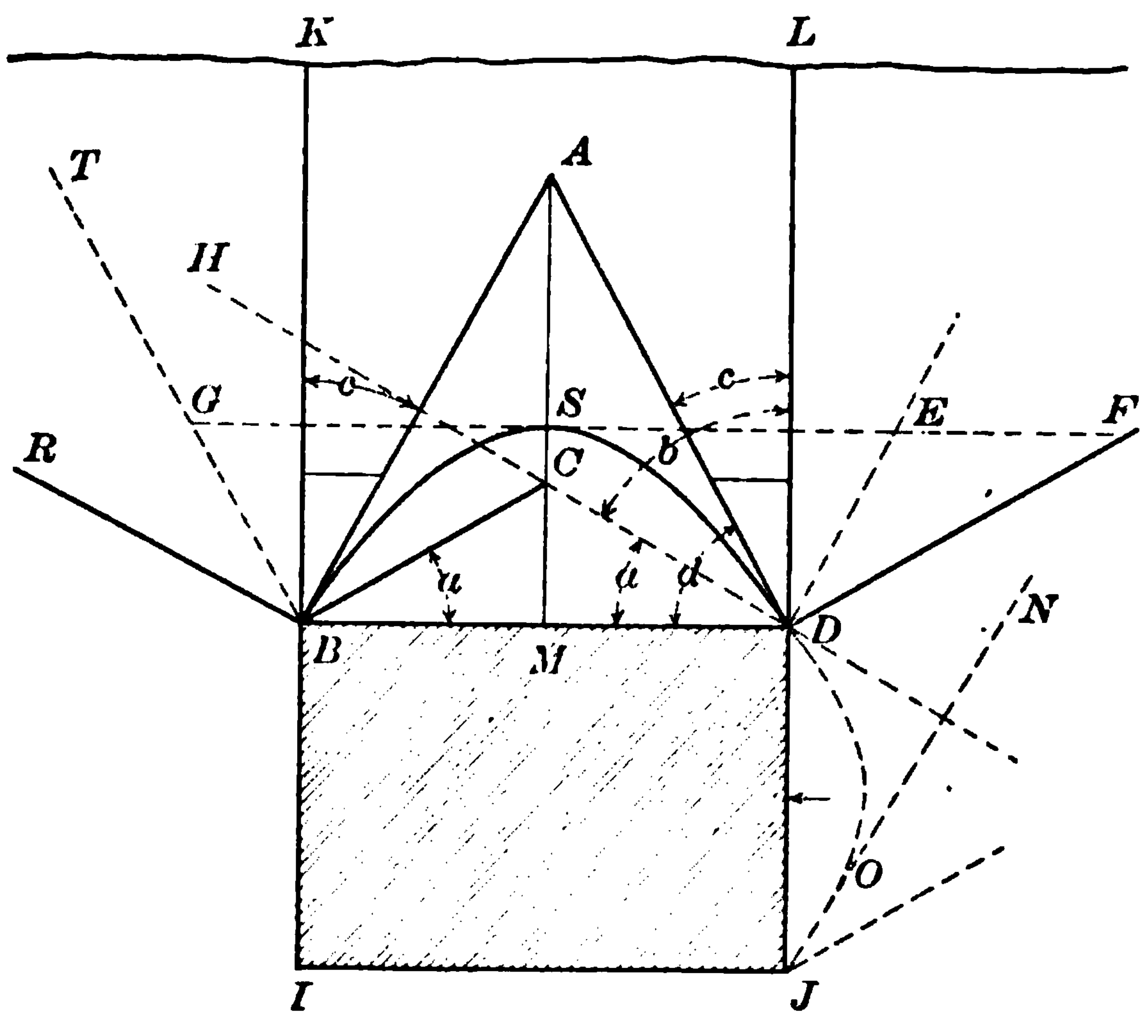


FIG. 9.

the roof would be that due to the weight of the material below this line. In order to be consistent and carry out the line of reasoning in the original assumption, however, provision must be made for the pressures of all the material in the triangle, *B A D.* No pressure beyond the lines, *B A* and *A D,* can be transmitted to the tunnel unless the ground contains water in such quantities as to make the pressure hydrostatic. Of course, if the tunnel is a subaqueous one, the pressure on the line, *B D,* for purposes of practical calculation, must be that due to the hydrostatic head of the water measured by its depth to the line, *B D,* and by the width of the tunnel opening.

Returning again to earth pressures free from excess of water, it is found, of course, that the larger the angle, *a*, the greater is the resultant pressure upon the tunnel. It is possible that some may argue from this that the greatest pressure will occur in clayey soil where the earth stands vertically. This supposition, however, is erroneous, because, any soil which will stand vertically and continue to stand vertically under any circumstances must be considered in the same way as solid rock, and cannot be properly classed as material for which bracing is necessary. As a matter of fact, however, clays are treacherous soils for tunneling, and frequently develop pressures by squeezing or sliding horizontally, for which it is difficult to provide.

If, now, it be assumed that the square, *B K L D*, is made up entirely of blocks of ice (or frictionless solids) having an angle of repose of 90°, the full weight of this material would have to be provided for in bracing across the tunnel roof, *B D*. If, on the other hand, a material, such as dry sand, be considered, in which the angle of repose is very flat, the arching effect of this material comes more greatly into play by reason of its tendency to slide along the angle of repose, and therefore, the condition of least pressure that can come upon a tunnel in dry ground is where the angle of repose of the superimposed material is least, always providing the material is held by close sheeting. In a word, then, the greater the angle of repose the greater the pressure to be provided for, and this leads to the conclusion that dry sand of a small angle of repose would prove the best material for tunneling if it were possible to sheet and brace the roof absolutely without disturbing its equilibrium. In practice, however, it is, of course, impracticable to drive a tunnel through sand of any kind without having some movement of material, and the dryer the sand, the more likely it is to run through any opening in the sheeting.

Erroneous ideas of tunnel pressures may be had from the fact that any bracing which admits the slightest settlement develops in consequence greater or less pressure, according to the degree of settlement, and the consequent movement, which is permitted to take place, but the writer is convinced, from long observation, that in reasonably careful work no pressures need be allowed for beyond the limits herein stated.

Here, again, it may be of interest to note that if a frictionless material could be imagined, resting in a trough made by the prolongation of the lines, *R B* and *D F*, measuring the angles of repose, allowance would undoubtedly have to be made for the full pressure of the weight of all the material contained within the prolongation of the lines of rupture, *B T* and *D E*. Assuming a case where a tunnel is so close to the surface that the arching effect is lost, for instance, if in Fig. 9 the surface of the ground be taken at *G E F*, it is probable that there would be obtained not only the full pressure of the ground directly above the opening, but an increase due to the lines of rupture, *B T* and *D E*. Therefore, in the writer's judgment, it is always wise to discontinue tunnel operations when the surface of the ground intersects, or nearly intersects, the perpendicular line, *A M*; and it is within the reasonable limits of good practice to tunnel when the surface of the ground is fairly well above the point, *A*. It may also be of practical interest to note that any longitudinal trenching should always be avoided if possible over the line of a tunnel while it is being excavated owing to the consequent destruction of the key to the arching effect of the ground.

As to the actual pressure:

Let $l =$ the width of the tunnel;

$A\ M = h = \frac{l}{2} \times \tan.\ d.$

Then the area, $B\ A\ D = \frac{l\ h}{2}$;

and, assuming that $a = 34°$, then $c = 28°$ and $d = 62°$;

and the tangent of $d =$ approximately 2;

and l, of course $= h$.

The area, $B\ A\ D$, therefore, becomes $\frac{l^2}{2}$,

and $\frac{w\ l^2}{2} =$ the total weight per linear foot of tunnel,

where $w =$ the weight of earth per cubic foot.

As to side pressures, the pressure against the sheeting, *D J* (Fig. 9), continues along a line of rupture, *J N*, stopping at some indefinite point, which, for practical purposes, may be taken at *O*, and making the only actual pressure in closely-sheeted work approximately within a line measured by the curve, *D O J*. An

excess allowance covering conditions of sheeting, ground, etc., in which judgment is a large factor, should be used in all calculations relating to the question of side bracing, to give a proper factor of safety in connection with this somewhat indeterminate quantity.

As to the question of shaft bracing, Fig. 10 is a cross-section of a square shaft of an area sufficiently small to give the surrounding earth a tendency to arch itself horizontally, it being very probable that such a shaft of reasonably small dimensions and driven as here shown will develop pressures somewhat as indicated by the circumscribed circle. It appears to be reasonably fair to assume that a circular shaft of not too large diameter, driven in dry ground or moist sand, will arch itself so that very little pressure is exerted

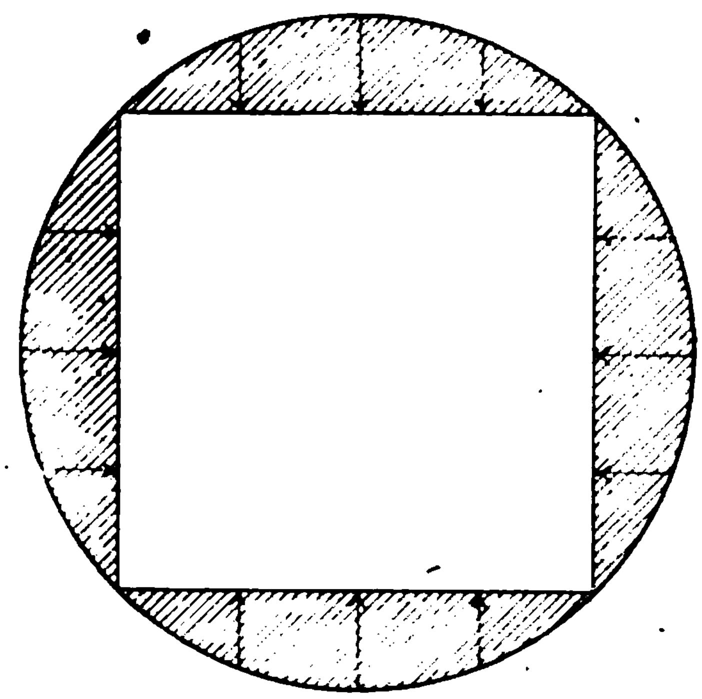


FIG. 10.

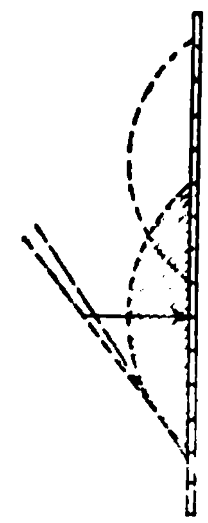


FIG. 11.

on the bracing in excess of that originally developed in making the sheeting and bracing tight. This excess pressure is small and indeterminate in actual practice, and may be measured by the intersection of the lines of the arching effect in a horizontal plane and the lines of rupture in a vertical plane, and somewhat as shown in the vertical section in Fig. 11. This pressure varies, of course, in direct proportion to the care with which the sheeting was originally placed. In view of this, it is true, both practically and theoretically, that a small shaft may be driven to any depth without developing any greater pressures below than are found near the surface. As soon, however, as the shaft becomes so large that the horizontal arching effect is destroyed, the action of the pressures becomes the same as the bracing in an open trench, and therefore

it would be impracticable to sink to any great depth a shaft the dimensions of which were such as to put it in the same category as trenches.

Attention is called to the photograph, Fig. 2, Plate LXX, which shows an underpinning pit sunk to a depth of about 18 ft. by the use of horizontal or well-diggers' sheeting. The bottom of this pit is at the level where ground-water has been struck, and is there sheeted with interlocking steel sheet-piling driven some 5 ft. into the ground to bring its toe well below the sub-grade of the adjoining excavation for which the underpinning is required. This pit can now be pumped out and excavated without danger of bringing in sand, and can then be filled with concrete to form a proper foundation for supporting underpinning timbers. The writer has personally supervised the work of sinking numbers of similar pits for different purposes, some to depths of 45 ft., without other bracing than the horizontal sheeting noted above, each set alternately bracing the other. It is also known that pits of this character, and not more than 5 ft. square, have been sunk by well-diggers to a much greater depth than those noted without using any bracing other than the sheeting of the character described above.

The writer believes that the practice of lining circular manholes with masonry walls the thickness of which increases with the depth is not consistent with good designing, and that a circular shaft may be safely designed with a masonry wall which has the same thickness at an indefinite depth as it has near the surface.

The remainder of this paper illustrates and discusses a few general types and methods of sheeting and bracing.

The ordinary sheeting, of course, is hand-driven vertically, as previously illustrated, but it is not always possible to drive sheeting, particularly in subway work, where much of the excavation has to be done under cover. In such cases, however, it is always possible to use cross, box, or horizontal sheeting, types of which have been illustrated in connection with the sinking of pits. This type of sheeting, of course, is more expensive to put in, but in some instances gives better results than its hand-driven prototype, as the work can be done more carefully and can be more closely watched to avoid the occurrence of voids behind it. It may be of passing interest to note that the writer on one occasion found a

void larger in size than the hand of an ordinary man behind sheeting which had stood for fifteen years in a clayey soil.* He does not desire to offer this as a reason, however, or even a good excuse, for leaving such voids.

The general type of bracing shown in Fig. 12 may be taken to illustrate the more usual methods in connection with openings as

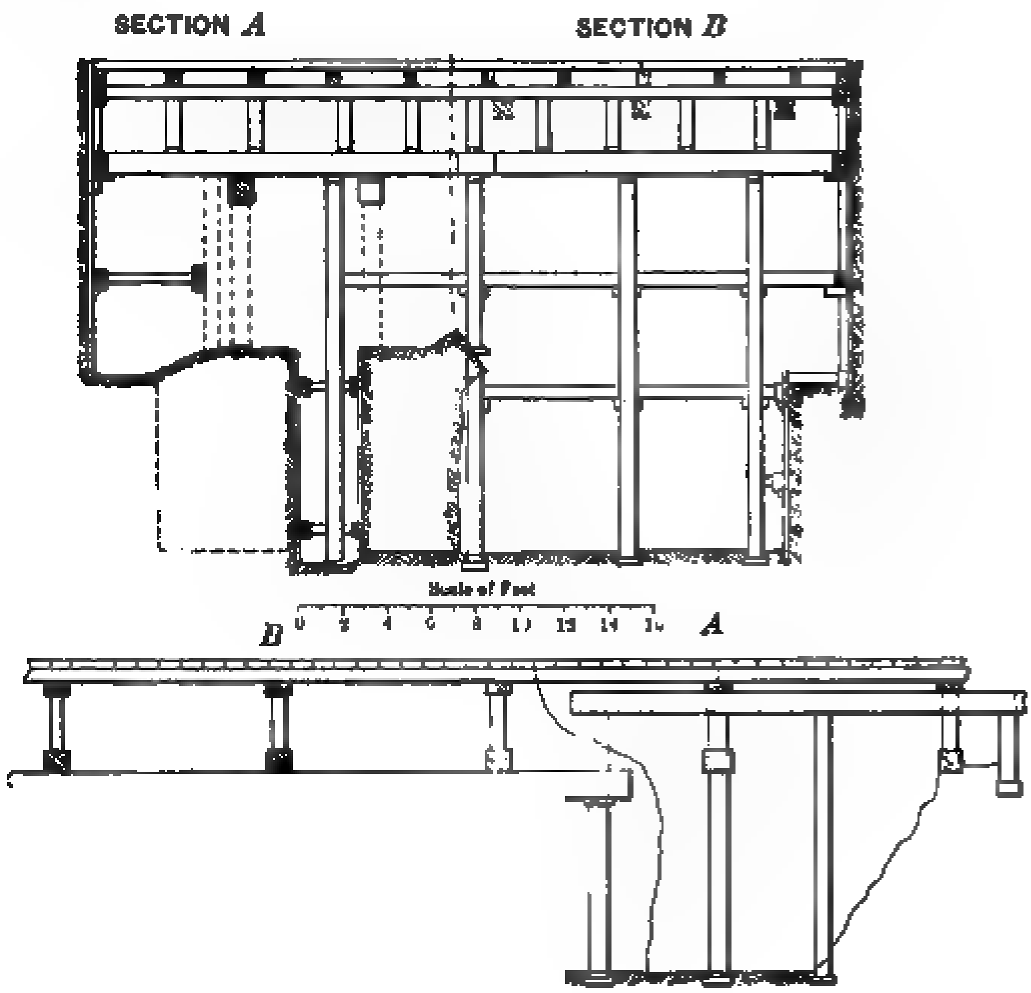


FIG. 12.

large as those required for the ordinary two-track subway. The general scheme in this is to dig the excavation in two or more levels, according to the depth, completing the excavation for a portion of one level before the other is begun. The decking is put in and

* Since preparing this paper the writer's attention has been called to a void recently found in excavating over a tunnel driven fifteen years before in sand. This void was large enough to admit one-half the body of a man.

carried on longitudinal sills, which, in turn, are braced from a lateral cap or caps, as shown, and where interference of pipes does not prevent. From this point the main cap is carried on temporary longitudinal I-beams or timbers of sufficiently large section and length to span from the solid ground ahead to the posting behind and carry one or more caps, according to the size and weight overhead. In carrying the excavation to its final level, after the first portion has been excavated, long posts, reaching from the main cap to the bottom, are put in in pits, as shown; or, if the longitudinal bars supporting the caps are sufficiently heavy and the superimposed weight is not too great, they may be put in in open excava-

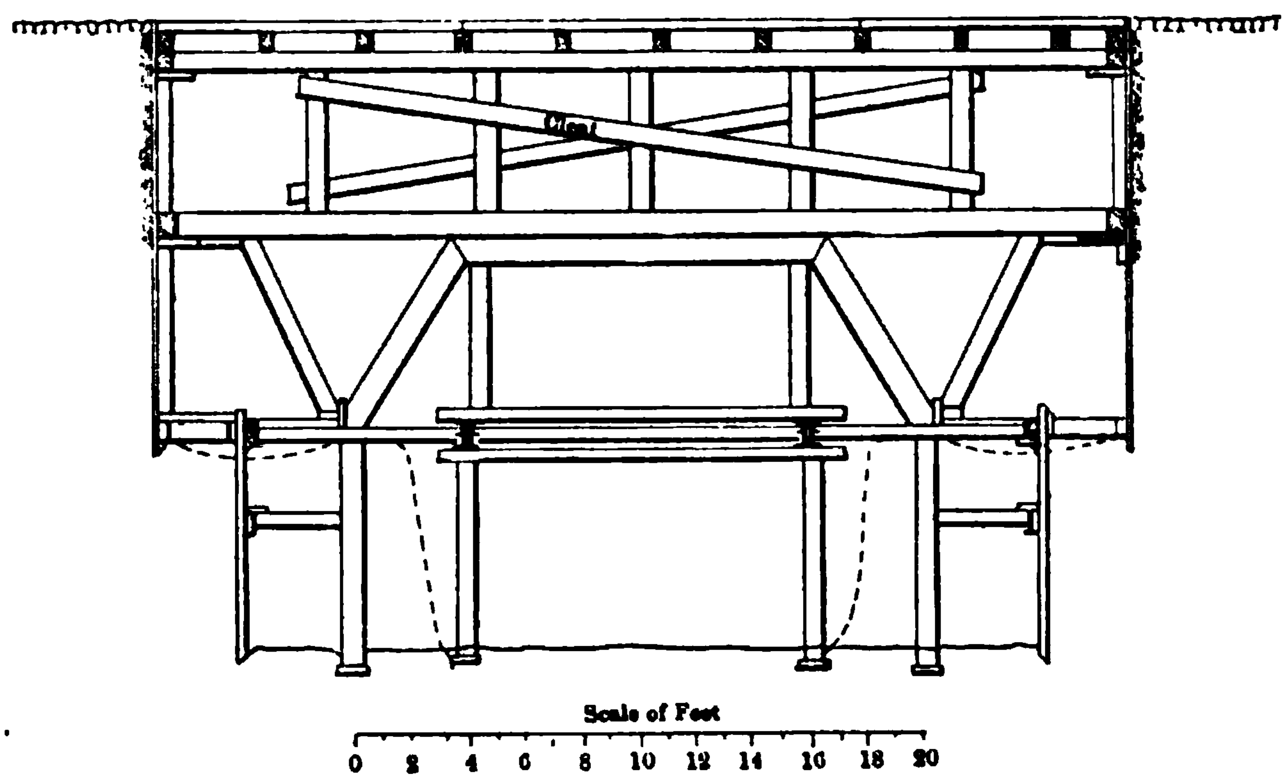


FIG. 13.

tion, as shown at the upper right portion of Fig. 12. The advantage of operating by this method is that the long posts, when once in place, give a vertical stability to the structure; but at the same time they are more or less cumbersome to handle, and not infrequently have to be cut up to be removed. Of course, the presence of pipes or other sub-surface or surface structures must change the form of bracing very materially, and the nature of the ground may also make considerable change in the method of operation.

In Fig. 13 is shown a type of bracing which has been used by Cranford and McNamee, in Brooklyn, in connection with their subway work. In this the decking where required is carried on longitudinal stringers, and where there are trolley tracks they are

carried on longitudinal I -beams. As close as possible to the top of the trench, and below the general line of the pipes, needle-braces are run from ranger to ranger, and below this a cap is set. This needle and cap are carried on temporary posts and rakers until the heavy side rakers or inclined legs shown in Fig. 13 can be put in. The built-up, continuous, channel-beams, shown in cross-section beneath the main cap, are then run ahead, and the posting is carried up from that. The excavation is then carried down along the dotted line (and sheeted, if necessary), and the main posts are put in under the channel beams, the load being carried on the diagonals while this is being done. The excavation is then widened to its full limit.

The "bench" shown on each side of the excavation serves the double purpose of allowing for the construction of the side sewers and forming a break in the pressure area measuring the thrust of the bank. It is believed that, even where sewers are not required, it is a wise precaution to maintain some form of bench at or near this point.

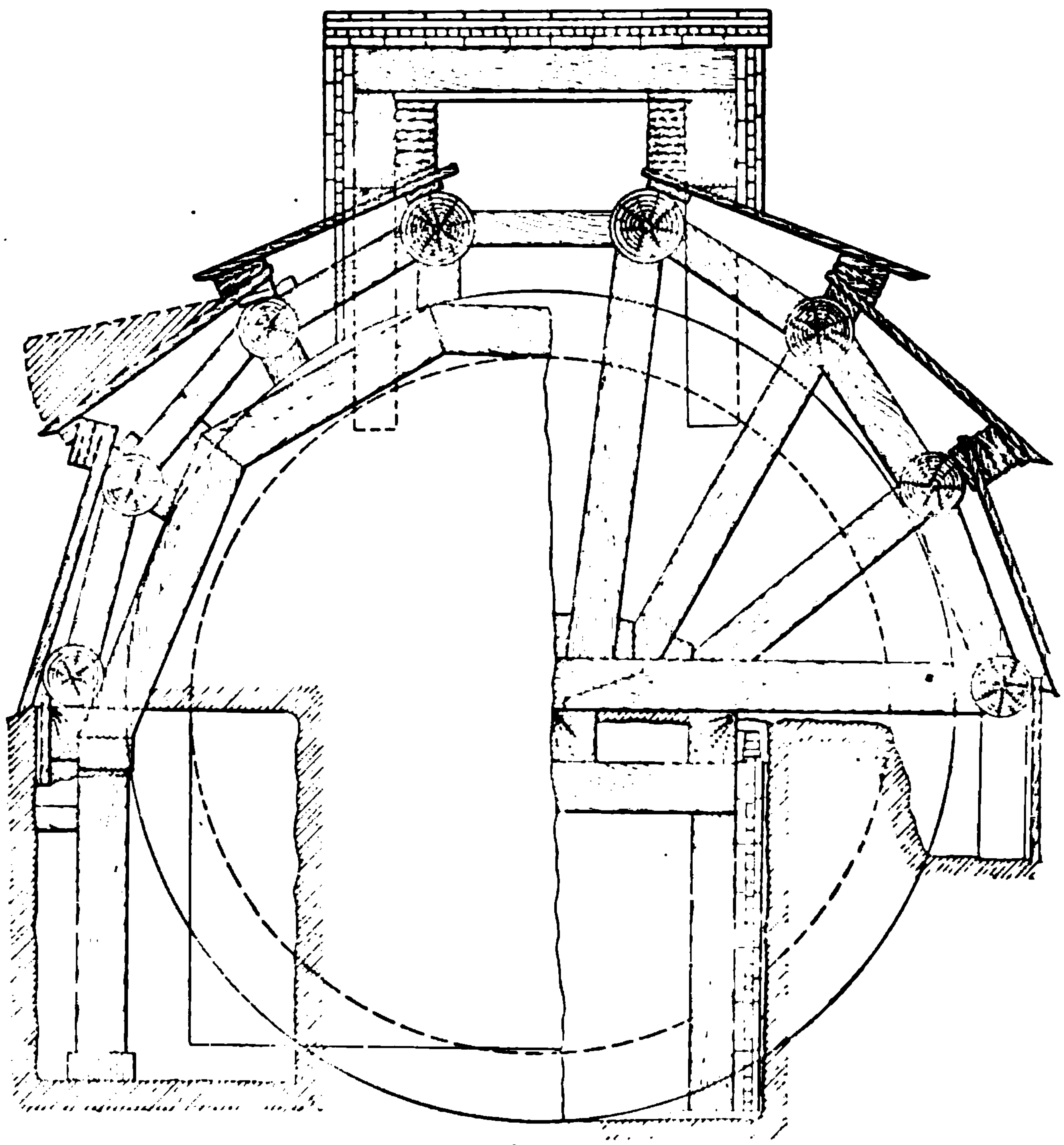
The advantages of this type of bracing are that it does away with the necessity of using long, heavy posts and temporary, long, heavy beams, as the longitudinal channel-beams make a tie which gives absolute stability to the shorter posting.

The interesting feature of Fig. 13, in connection with this paper, is that the heavy main brace, called the needle-brace, which runs from ranger to ranger, was calculated to do the heaviest work of the bracing, and was put by the contractors as nearly as possible at what they conceived to be the center of the heaviest pressure. The writer is thoroughly familiar with the work which this main brace has been called upon to do (in one instance it spans a continuous excavation for a six-track subway, and braces and carries the bracing for a double-track surface line and a double-track elevated railroad), and he can say positively, from his own knowledge, that at no time have the contractors ever seen fit to modify their first design of putting this main brace near the top rather than near the bottom of the trench.

Fig. 1, Plate LXXI, is a view of a section of this type of bracing for a four-track subway in Fulton Street, Brooklyn, and Fig. 2, Plate LXXI, shows the surface lines and bracing carrying the

columns of the elevated railroad, the supports of which are in turn braced directly by the timbering shown in Fig. 1, Plate LXXI.

In tunnel bracing, the writer is more familiar with two general types of timber-braced tunnels. One of these is the crown-bar



Alternate Views:
Right View shows Central Bottom Drift.
Left View shows Lower Drifts on side to set in Leg for Wall-plate.

Scale of Feet
0 1 2 3 4 5 6 7 8 9 10

FIG. 14.

system, shown in Fig. 14. It is not necessary to do more than call attention to the general features of this type. In the ordinary crown-bar system it is customary to drive the bottom drift ahead of all other work and follow this closely with a top drift, as shown

FIG. 1.—TYPE OF BRACING IN FULTON ST. SUBWAY, BROOKLYN.

FIG. 2.—A-FRAMES, SUPPORTING ELEVATED RAILWAY, OVER SUBWAY EXCAVATION, BROOKLYN.

in Fig. 14. The bars are placed in position in this top drift, the poling-boards are driven off approximately as shown, and the bracing is erected as the excavation proceeds. Where this type of bracing is used in rock tunnels it is, of course, unnecessary to drive a bottom drift, and the arch timber bracing shown on the left is usually put in underneath the bars as soon as the depth of excavation corresponding to the springing line of the structure has been reached. It is thus seen from Fig. 14 that, for the bar system alone, a circular tunnel of the size shown by the outer ring could be constructed, whereas with the arch timber bracing remaining in place, a tunnel no larger than that shown by the inner ring could be built.

The disadvantages of both these types of bracing are that so much space is required beyond the limits of the structure, and that it is impracticable to fill the voids over the masonry, even where dry packing of rock or brick is used; and it is virtually impossible to backfill them properly with sand or earth. Another disadvantage is the very prolific cause of settlement on account of the fact that the poling-boards do not finally rest in the plane at which they were started. This gradual lowering of the ends of these boards necessarily causes loosening of the material above and consequent settlement, with increased loading on the bracing, and while these items may not be of material importance in open country, they should be given the gravest consideration where this system is used under city streets.

Where arch timbers have been used, as in a few cases, in connection with the crown-bar system, and put in sufficiently high to clear the outer ring of the tunnel, it has been sometimes customary to run two bottom drifts ahead (as shown at the left of Fig. 14), setting in supports for the wall-plates before the upper excavation has been made. There are some instances on record in which the wall-plate has been directly underpinned after being put in place with a load on it. The writer has supervised the work of building tunnels of large diameter, and in one of the headings the arch timbers were used in connection with the crown bars and afterward removed; but in the remainder of the work with which he is familiar the arch timbers were used in connection with a special type of timbering shown in Fig. 15, all of which was eventually removed, leaving the tunnel sheeting bearing directly on the brick-

work. In this type the arch timbers were underpinned from the masonry which was put in in a centrally sheeted and braced trench, as shown, the entire masonry of the structure being built in three successive stages, of which the first is that noted in the bottom of the trench. In this method the outward thrust of the bottom legs of the arch, or segmental timbers, precludes almost entirely the possibility of any settlement while the sheeting for the middle trench is being driven. In dry ground there is practically no danger of any settlement to be caused from this method of under-

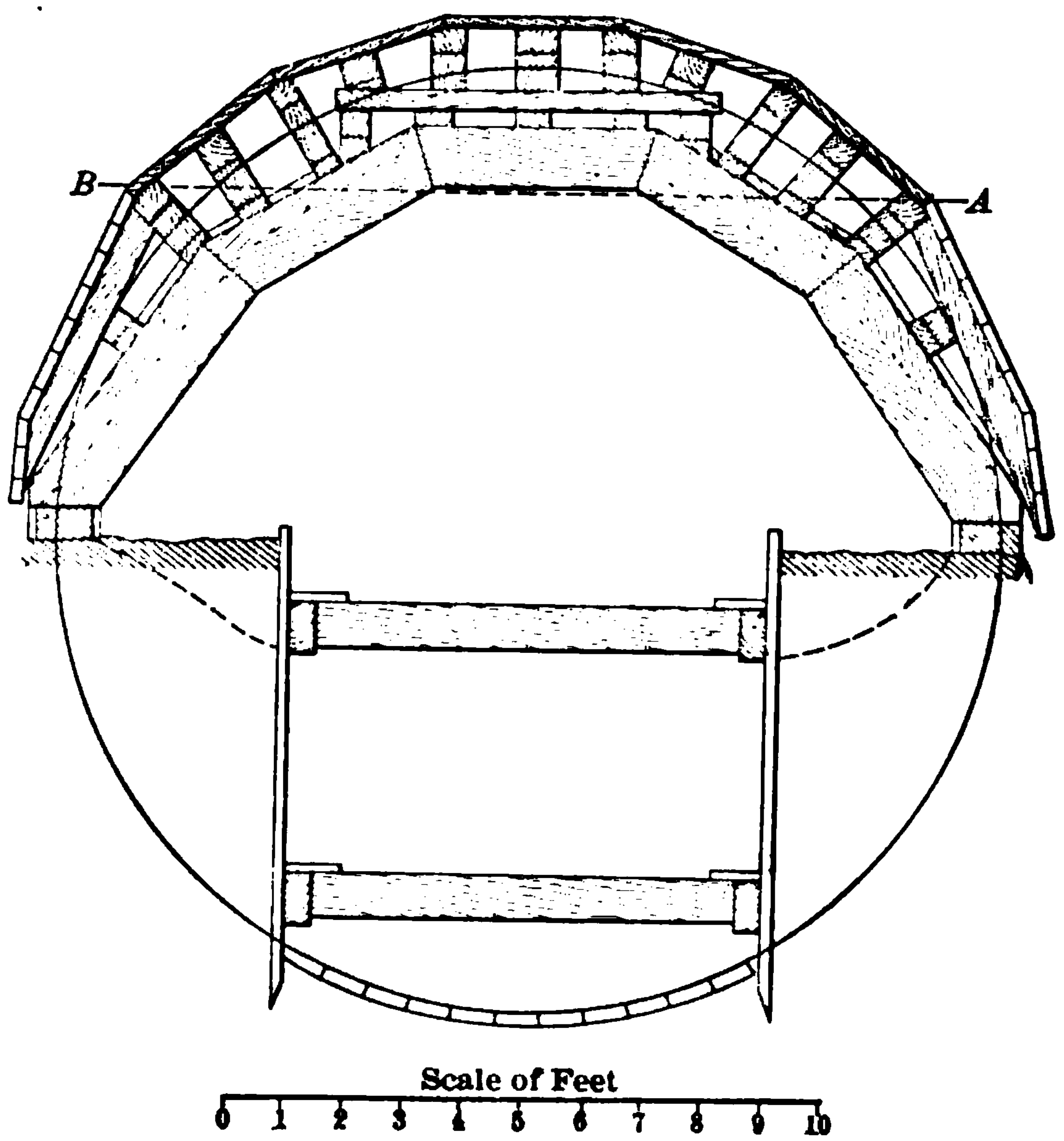


FIG. 15.

pinning, and the writer has supervised tunnels built safely by this method, where the ground-water level was normally 5 ft. above the sub-grade and had to be kept down by constant and heavy pumping through sand.

It may be of interest to state, in connection with the action of earth pressures, that it is almost always practicable to set in horizontal sheeting below the line, *A B,* in Fig. 15. In cases where the sand is moist and not too gravelly, very little difficulty is ex-

PLATE LXXII.
PAPERS, AM. SOC. C. E.
AUGUST, 1907.
[redacted]
BRACING, AND EARTH PRESSURES.

ARCH TIMBERS SUPPORTING RAISED TUNNEL ROOF.

The Committee on Geology makes some statements that do not seem to be entirely in accord with the conclusions of the Committee on Buildings. It states: Mr. Stern.

"The damage to buildings, while large, was confined to those faulty either in design or in construction."

And:

"The results, so disastrous to buildings and engineering structures, can and will be provided against in the future."

This statement is not concurred in by the Committee on Buildings, which, in its report, says:

"Obviously, the shock may range from a tremor to that of a violence that would wreck any building."

And also:

"Should the earth-slip take place beneath a building, it would be wrecked."

To prove that the quality of workmanship, while important, is still not sufficient to prevent a disastrous wreck, the Committee on Buildings cites the case of St. Patrick's Academy, in which the brick walls were so well laid up in Portland-cement mortar that the walls invariably broke through the brick instead of the mortar joints.

The first thought that comes to one's mind is that a limit should be placed on the height of buildings. The higher the building, the more disastrous must be the whipping and gyratory effect of the earthquake. It is to be regretted that the Committee on Buildings makes no recommendation on this point.

It reports that while the injury to steel frames in buildings of Type 4 (in which the entire structure, including brick walls, was carried on the steel frame) was inconsiderable, the enclosing walls of brick or mortar were damaged to a greater or less extent, and will require extensive repairs. It cites the case of the Claus Spreckels Building, in which the stonework was badly worked on the beds above the tenth story; also that of the Chronicle Building and others in which the brick, stone, and terra-cotta work were badly cracked. While it recommends that for rear walls reinforced concrete offers the best solution, the reinforcing members being tied to the steel frame, it is illogical in recommending that the fronts be made of brick, terra cotta or stone tied to the steel frame, in so far as its own report shows that the motion of the earth tended to shatter the bond in brick and mason work.

If brick and masonry walls shake loose during an earthquake shock, let these materials be abandoned for something better.

It would be of great interest to know what damage resulted to buildings of Type 4, which were located on or near the fault line. The reports have not mentioned any cases of this kind.

Mr. Stern. As a class, the steel frame seems to have been the only form of construction that came through the earthquake at all satisfactorily, although the Committee reports damage to structural frames that will have to be repaired.

It states that the prime requisite of the structure is elasticity, which is reasonable; but should not provision also be made for inequality of settlement of foundations, as well as the vibratory effect of the quake? It is not always certain, in earthquake shocks, that the soil under foundations will not settle.

The speaker cannot conceive that a thoroughly rigid structure is the right one to build, but rather one that is designed for vibratory and swaying motion, and, at the same time, has sufficient flexibility in the joints, so that in case of unequal settlement of foundations it can be repaired at very much less expense than one in which no allowance for this has been made.

Regarding foundations, the Committee states that no instances of damage have come to its notice. Does this mean that there has been no unequal settlement of foundations, or that none of the foundation piers have been shattered, or what is the meaning? The speaker would recommend that isolated piers be firmly tied together at the level of the bottoms of columns.

The catastrophes at San Francisco and Kingston are still fresh in our minds, but there have been other very destructive earthquakes in comparatively recent times, and it might be well to review briefly some of the most disastrous of these.

In 1822, in Chili, an earthquake shook the coast for a distance of 1 200 miles north and south, and the coast line was elevated from 4 to 5 ft. for a distance of 35 miles.

In 1835 and 1837, also in Chili, there were disastrous earthquakes in which towns were destroyed and the coast was raised to a height of from 4 to 8 ft. for a distance of more than 100 miles.

In 1891, in the Provinces of Mino and Owari, in Japan, a severe earthquake occurred in which 7 000 people lost their lives and 17 000 were wounded, 197 000 houses were wholly demolished and 78 000 more than half demolished. A fault occurred, which extended entirely across the island, the vertical displacement being from 9 to 18 ft. and the horizontal displacement about 6 ft. A levee was moved bodily 60 ft., carrying a thicket of bamboo and pine trees. The area shaken was estimated at approximately 95 000 sq. miles.

In 1897, in the Provinces of Bengal and Assam, in India, there was an earthquake the effects of which extended over 1 750 000 sq. miles, many dislocations of the earth taking place, both vertical and horizontal, amounting in some places to 30 ft. The violence was so excessive that not a masonry structure in a district covering 6 000 sq. miles was left standing. Monuments and tombstones were de-

stroyed, and trees 6 and 7 in. in diameter were broken through the trunks by the swaying motion of the earth. Mr. Stern.

The recent earthquake at Valparaiso, in August, 1906, caused a loss of more than $250 000 000 in property, and destroyed, besides, 140 smaller towns and villages. More than 1 000 people lost their lives.

In January, 1907, the City of Kingston, Jamaica, was destroyed, the loss of life being about 1 000.

The Province of Guerrero, Mexico, in April, 1907, was visited by an earthquake which destroyed several towns and caused a loss of life of more than 100.

M. de Montessus de Ballore has tabulated the number of seismic occurrences which have been observed during the nineteenth century, amounting to the enormous total of 131 292 quakes, and 10 500 epicentra.

In view of the foregoing facts, it must be admitted by the candid student that the problem of constructing buildings in earthquake districts so as to withstand entirely the violence of some of the excessive seismic disturbances is a difficult one.

Destruction of property cannot be prevented, but the excessive loss of life and property through the improper construction of buildings can and should be very largely reduced.

It is an engineering possibility to design a structure—a ship, for instance—that will stand any kind of strain, and adapt itself to all manner of conditions. It is also an engineering possibility to design a building so that it will stand a great deal of shock, besides some inequality of settlement of foundations due to a distortion of the earth supporting it.

A proper adaptation of such structures to the needs of those occupying them is a modifying condition which, together with the architectural requirements, has to be considered in the problem. Primarily, it is a question of applying sound engineering principles to the question in hand, and architectural features should be subordinated to these.

The important lessons of the San Francisco disaster, as regards the construction of buildings in earthquake districts, seem to the speaker to be:

1.—That buildings should not be constructed more than 100 ft. in height.

2.—That all structures in the business sections of the city should be fire-proof.

3.—That fire-proof structures should have a frame in the design of which swaying and gyratory motions, as well as unequal settlement of foundations, should be provided for; and that this frame should carry the walls at every floor.

4.—That the best material thus far known for such a frame is steel.

Mr. Stern. 5.—That the floors, walls, and partitions should be of reinforced concrete in which the reinforcing members are securely tied to the steel frame.

6.—That the water and gas pipes, and electric wires, should have special ducts, and the practice of carrying these next to the columns and surrounded by their fire-proof covering cannot be too strongly condemned. There should be expansion joints in the water and gas pipes, in order to avoid breakage in case of settlement of the building.

Mr. Freitag. J. K. FREITAG, ASSOC. M. AM. SOC. C. E.—Referring to the "Report of the Committee on Fire and Earthquake Damage to Buildings," especially that portion dealing with the fire damage, it would seem that certain broad and vital principles relating to fire-resistive construction in general have not been sufficiently emphasized, but have been made of secondary importance to descriptions of damage of mere structural detail, and to consequent recommendations deduced therefrom.

The first conclusion* of the Committee is:

"Any deductions from the fire must be those based upon a general conflagration, and not those of an isolated fire. In view of the complete destruction of all materials it becomes a question as to what should be done to make a building fire-proof."

This conclusion, although somewhat amplified in a succeeding paragraph, which will be discussed later, seems to place altogether too much emphasis upon the possibility of making an individual structure fire-resisting under conflagration conditions. Previous conflagrations, notably that of Baltimore, have shown the almost utter futility of attempting to cope with fire when once it has reached the proportions of what is generally called a conflagration. No structural materials of which we have present knowledge are equal to the task of resisting successfully such severe test conditions, at least to a point which would justify any reliance which might be placed upon their use.

Further, if the high temperatures, the multitudinous points of attack, and the general impotence of all fire-fighting measures obtainable during a conflagration are to be entirely overcome, then the task of fire-resistive construction is surely a hopeless one, and those interested in fire-resistive principles might well be dismayed at the records of Baltimore and San Francisco. The Committee evidently realized this aspect of the question, for it states that:†

"Unless one has been an eye-witness, it is difficult to realize how all materials that men make into the shape of buildings can be so utterly destroyed in a general conflagration."

If, then, that fact is once admitted, as it must surely be by those thoroughly familiar with the tests of fire-resistive methods afforded

* *Proceedings*, Am. Soc. C. E., for March, 1907, p. 332.

† *Proceedings*, Am. Soc. C. E., for March, 1907, p. 328.

by the Baltimore and San Francisco conflagrations, the main question becomes, not so much what can be done to make any particular building fire-proof, using this or that detail of concrete or terra cotta, or one or another construction of exterior walls or partitions, etc. (though all these points are of immense value as details of the larger problem), but what can and should be done to prevent conflagrations? The Committee's answer to this most vital problem of the American people is far from satisfactory. Mr. Freitag.

Statistics as to the annual fire losses in the United States are probably familiar to all who are interested in building construction. Let it suffice here to recall a few figures. The fire loss in the United States has now approximated $200 000 000 annually for several years, during normal conditions, *i. e.*, years which have not included widespread conflagrations. Add to this direct loss the expense of maintaining fire departments, etc., and the money paid to fire insurance companies in the way of premiums, and it is questionable whether these financial losses do not equal, or even surpass, the value of all new buildings erected throughout the United States within the year for which the comparison is made. Including the San Francisco conflagration loss, the year 1906 becomes an abnormal one, and the fire-waste alone, not counting fire departments or insurance premiums, is estimated at not less than about $506 000 000, while the estimated value of new building operations in the United States for the same year probably approximates $575 000 000. Hence no more vital economic problem is before our people to-day than the lessening of this stupendous drain.

Before considering the responsibility which lay before the community of San Francisco in making impossible a repetition of at least their share of this fire loss, or the same responsibility which lies before all cities, it will be pertinent to inquire into the conditions which made this great calamity (by fire) possible.

The report of the Committee states that:

"San Francisco was built probably in about the same way as other cities. It is an error to say that it was a wooden-frame city, as the business district was generally composed of buildings with brick walls. In among these had been constructed the so-called fire-proof structures, exposed on all sides to danger by the burning of the inflammable structures around them."

That San Francisco was not considered by insurance interests to be built "in about the same way as other cities," is made most clear in the Report on the City of San Francisco, issued in October, 1905, by the "Committee of Twenty" of the National Board of Fire Underwriters. The general summary of that report, page 64, reads as follows:

"Conflagration Hazard.—*Potential Hazard.*—In view of the exceptionally large areas, great heights, numerous unprotected

Mr. Freitag. openings, general absence of fire-breaks or stops, highly combustible nature of the buildings, many of which have sheathed walls and ceilings, frequency of light wells and the presence of interspersed frame buildings, the potential hazard is very severe. *Probability Feature.*—The above features combined with the almost total lack of sprinklers and absence of modern protective devices generally, numerous and mutually aggravating conflagration breeders, high winds, and comparatively narrow streets, make the probability feature alarmingly severe.

"SUMMARY.—While two of the five sections into which the congested value district is divided involve only a mild conflagration hazard within their own limits, they are badly exposed by the others in which all elements of the conflagration hazard are present to a marked degree. Not only is the hazard extreme within the congested value district, but it is augmented by the presence of a compact surrounding great-height, large-area frame residence district, itself unmanageable from a fire-fighting standpoint by reason of adverse conditions introduced by the topography. In fact, San Francisco has violated all underwriting traditions and precedent by not burning up. That it has not done so is largely due to the vigilance of the fire department, which cannot be relied upon indefinitely to stave off the inevitable."

The last sentence of this summary has proved only too true a prophecy of the calamity which followed only a few months after the publication of this report.

In discussing particularly the congested-value district, which contained about 2 100 buildings, *Insurance Engineering* gave the following summary of the types of building construction:

Fire-proof.	2.2	per	cent.
Brick and wood joist	68.3	"	"
Frame construction	29.5	"	"

In further description of this area, the same journal stated as follows:

"In the congested value district there was but one sprinkler equipment and it was practically obsolete. One hundred and twenty buildings contained stand-pipes and hose, and a few small fire pumps drawing from deep wells. * * * All the fire-proof buildings had windows unprotected, and in many cases were badly exposed. About 50 per cent. of the joisted brick buildings had furred and wood-sheathed walls and wood-sheathed ceilings. * * * Large, open light wells were numerous, and conspicuously prominent on account of their size and number. Several of the older hotels were literally perforated with them. * * * About 90 per cent. of the entire city and 30 per cent. of the business section were of frame construction, brick buildings being confined almost entirely to the fire limits, and San Francisco could be justly termed a wooden city."

The above criticisms of San Francisco's buildings would be severe enough—indeed far too severe to be pleasant, as applied to any

large city—but, when applied to a city in a locality subject to seismic disturbances, the facts become a severe indictment, and show either the indifference of San Francisco's citizens, or the ignorance or carelessness of the Building Department. Municipal regulations (whether or not in a locality subject to earthquakes) which permit 30% frame construction within a congested-value district, which permit buildings of masonry walls and timber floors and partitions to be eight stories, or 100 ft., high, which permit "large private hotels and apartment houses of this type," which provide no limitations as to undivided areas, and which allow the "absence of modern protective devices generally," are most certainly insufficient, short-sighted, and unjust, and most particularly unjust to those investors who improve their property by erecting steel-skeleton fire-and-earthquake-resisting buildings, and then have them "exposed on all sides to danger by the burning of the inflammable structures around them." **Mr. Freitag.**

This brings up the consideration of civic responsibility, as applied to building construction. European cities long ago learned the lesson that safety to the individual means safety to the whole community, and *vice versa.* Witness the most ineffectual fire departments in most continental cities, and, withal, the trifling fire-losses, and, especially, the almost total absence of conflagrations, or even the spread of fire to immediately adjoining property in the cities of civilized Europe. The reason is to be found entirely in the matter of building construction. A building which will prove a menace to neighbors cannot be erected, and the responsibility of the individual as affecting the community is even carried so far in some localities of Europe that the owner of property causing fire damage to neighbors is held financially responsible for such loss.

It is just some such civic responsibility which is needed, and needed very soon, in all large American cities. Responsibility of the individual to the community, which will cause the individual to contribute to the public safety in matters of building construction by erecting structures which will not prove a menace to his neighbors; and responsibility of the community to the individual, in that those investors who improve their land by the erection of costly and permanent structures shall not be allowed to suffer constant hazard through irresponsible neighbors who have no thought or care of their civic duties.

It is now a trite saying that "fire-proof buildings must stand in fire-proof cities," but this statement contains the whole truth of the matter of fire-resistance. If American cities are not to suffer such conflagrations as have occurred at Chicago, Boston, Paterson, Baltimore, and San Francisco, besides many other lesser ones; if the realization of this tremendous financial drain is once grasped in an effort to lessen it; if it be admitted that isolated buildings surrounded by severe risks cannot withstand conflagration conditions, then the

Mr. Freitag. achievement of fire-proof cities (or at least the congested areas therein) must be made possible by uniform fire-resisting construction throughout.

Touching upon this point the Committee states as follows:

"The only statement that can be offered is that the best insurance for buildings would be the isolation of a district containing nothing but fire-proof structures. A general conflagration would then be impossible. Manifestly, this is impossible in San Francisco, where business must be resumed with the least cost. In many cities, it would be good insurance for men owning large buildings to combine to buy out old and inflammable structures, either demolishing or rebuilding them. Otherwise, there remains the danger of general conflagrations, such as those at Baltimore and San Francisco, in which fire-proof buildings will be injured from 30 to 60 per cent."

With the first statement, regarding the isolation of congested districts to contain nothing but fire-proof structures, the speaker most heartily concurs, not only because such practice would afford the "best insurance for buildings," but also because it would afford a maximum of safety and assurance for the whole community. With the statement, however, that "this is impossible in San Francisco, where business must be resumed with the least cost," or, indeed, that uniform fire-resisting construction is impossible in any city ready to take the lead; and also with the suggestion that "it would be good insurance for men owning large buildings to combine to buy out old and inflammable structures," etc., instead of throwing some such responsibility upon the city itself, the speaker begs to take most decided exception.

In the United States we are so prone to consider the rights of the individual that we are apt to overlook the rights of the aggregation of individuals. It is not denied that municipal building regulations adopted by any city, requiring uniform fire-resistive building construction after any fixed date, would give rise to seeming injustices and hardships, but if laws requiring the remodeling of present risks were also rigidly enforced, in addition to laws covering the erection of new buildings, the hardships would soon be equalized, and benefit accrue to the community in the way of reduced fire losses, reduced insurance premiums, reduced expenses for maintaining fire-fighting equipments, and added security to life and property interests.

"The fire problem, meanwhile, is with us, and it is not only for future buildings that we are concerned but with those that exist at present. Out of 300 000 buildings in the Metropolitan district (New York) not more than 2 000 are classed as thoroughly incombustible. With the remaining 298 000 we have got to deal. That these buildings can be made practically fire-proof—the word is used advisedly—is a statement which is not only capable of

demonstration, but has already been demonstrated by fire experience. Mr. Freitag.

"To safeguard these buildings is an engineering proposition pure and simple. The knowledge and ability are available and there is required simply a desire on the part of occupants and property owners. A very large percentage of the causes of fires is known, and can be eliminated from a building; there are on the market devices and systems of proved worth for detecting such fires as do occur, and for extinguishing them by automatic or manual means; a building can be planned to limit the area of fire; it can be prepared to facilitate the work of the public fire department; it can be prepared to reduce the loss resulting from fire and water and thereby reduce the fire tax. This outlined plan makes a standard for judging fire conditions, and if applied to any particular building, it would register in a definite and precise form the degree of consideration which the owner or occupant has given to the danger of fire."*

W. W. Harts, M. Am. Soc. C. E. (by letter).—To those who were present during the recent San Francisco earthquake, it requires no stretch of the imagination to believe that there might easily occur an earthquake of such intensity as to defy human skill to construct an edifice, anything like those now built, which would be able to withstand its power. The writer's experience in Manila in December, 1902, led him to think, at the time of the San Francisco earthquake, that the results in the city would not be very serious. That earthquake was not only longer in duration than the San Francisco shock, but was believed to be greater in the amplitude of the vibrations. The damage in the Philippines was slight, as buildings are purposely kept low, and are erected cheaply, with the earthquake hazard constantly in mind. Had it not been for the destructive fire in San Francisco, it seems safe to say that the earthquake and its results would have been only a nine days' wonder. Mr. Harts.

To what extent it seems necessary to provide for earthquake stresses in buildings, is a question of great nicety and careful judgment. It can scarcely be stated in pounds per square foot of superficial area, like wind pressure, which soon reaches a limit, although this method has been suggested. It partakes far more of the nature of insurance, so that, although there might be placed no limit to the expenditure for the protection of buildings from damage from this source, still an economical consideration will very quickly place a limit beyond which it is not desirable to provide against such risks.

The probability of the recurrence of dangerous shocks, and the estimate of the intensity can only be surmised. The additional expense, required in a structure for protection, therefore, would appear rather to be some percentage of the value of the building,

* *The Journal of Fire.*

Mr. Harts. if such protection were to be calculated upon a proper basis. That some protection for valuable buildings is advisable, is borne out by the admirable resisting powers of the Call Building. On the other hand, it is easily conceivable that small buildings might be built satisfactorily without any special reinforcement, should it be more desirable to run the risk of destruction than provide for protection. It is unquestionable that the class of buildings resisting the earthquake stresses most satisfactorily have been those in which a certain amount of elasticity was found, permitting the building to yield to the shock and return to its true position without injury. There appear to have been many cases where brick buildings, well constructed, complied with these conditions, and the many examples of brick buildings standing after both the earthquake and fire had done their worst, is a sufficient indication that the sweeping assertion cannot be made as to the "hopeless inadequacy" of this type of structure. It is very dangerous, in any scientific discussion, to formulate sweeping general rules, and, in view of the evidence, the statement of the Committee, with reference to brick buildings, should be more explicitly modified. Furthermore, the explanation has been made that the test of engineering structures is not experience, and that the majorities cannot be relied upon, as in town meetings, to discover the truth as to their stability. Can it be maintained that the science of engineering is not the resultant of years of experience? Can it be said that successes are not guides and that failures are not warnings? The fact that wooden composition bridges for railways yielded to steel arose through no fault of the composite type, but through other causes, such as the increase in weight of rolling stock, increase in cost of wood and its short life, but mainly through the decrease in the cost of steel. Such a change has unquestionably been based upon economical and not altogether on theoretical reasons.

One of the earthquake features which does not seem to have been mentioned is the rotary effect of the shock. Evidence of this came to the writer's notice in examining the different gas holders on the North Beach water front immediately after the earthquake. In all the cases examined these holders were twisted in the same direction —counter clock-wise. Each one of the holders was twisted about 2½ ft., breaking the rollers from the guides. Of course, the holder was useless until put back into its place and readjusted. The actual motion of the earth was very slight, but the effect on these structures was very curious and noteworthy.

Mr. Rix. E. A. Rix, M. Am. Soc. C. E. (by letter).—The writer has often thought that the geographical structure of the San Francisco Peninsula has something to do with the character of the vibration which results at different points. For example: The writer's residence is on the summit of Russian Hill, on the solid rock, where the strata

appear to be very much uptilted. The shock there seemed to be felt principally in a vertical direction, and the writer was not conscious of any great horizontal movement. The shock on the hill was severe, but in his rooms nothing was thrown from the walls. In one room there was a pedestal, about 4 ft. high, on which was a statue which had an insecure base, but this was not disturbed. The writer, therefore, has wondered whether the vibration was not reflected by the underlying stratum; or whether the severe horizontal movement, felt in the lower parts of the city, was not translated, or a portion of it, into vertical movement when it reached uptilted strata. Mr. Rix.

W. F. Whitaker, Jun. Am. Soc. C. E. (by letter).—On the day of the earthquake the writer was running some levels in Bakersfield, Cal., and had great trouble with the bubble of his instrument. He knew that there had been an earthquake, but did not know that the quakes were continuing that afternoon. After the instrument had been nicely leveled, the bubble would move to one end of the tube. At first it was thought that the trouble was with the instrument, and another attempt was made to level it. After one or two trials of this kind it was discovered that if the instrument were left alone the bubble would move back to the center or perhaps to the other end of the tube. During the entire afternoon the same trouble occurred at intervals. The shocks were too slight to be felt. Mr. Whitaker.

The shock in the morning was felt by many, and caused some swinging of hanging objects. Although the writer was awake at the time, he did not know there had been an earthquake until told of it by others. In the evening, in discussing the peculiar action of the level bubble during the afternoon, the writer expressed the opinion that the shocks must be continuing, and learned later that this was true.

A. M. Bienenfeld, M. Am. Soc. C. E. (by letter).—A building under construction in Palo Alto, coming within the writer's notice, in which lime mortar was used, was badly wrecked, and it would seem that its destruction might be attributed to the use of the lime mortar. If all cement mortar, and no lime mortar, had been used, there would have been fewer wrecks of brick buildings. Mr. A. M. Bienenfeld.

The earthquake was not felt appreciably in Bakersfield, yet all the 70 or 80 steel tanks of the Standard Oil Company in that locality, which were filled with heavy viscous oil, were affected more or less. The tanks show that the oil spilled to the southwest, indicating that there was some tipping motion, or some motion of translation, sufficient to throw the oil in that direction. If there had been a return motion—oscillating, or vibratory—the oil would have spilled to the northeast, also, but the latter effect was not noted. It took about 2 hours for this phase of the earthquake shock to manifest itself at Bakersfield.

Mr. Adams. ARTHUR L. ADAMS, M. AM. SOC. C. E. (by letter).—It seems to be a question of definition and degree. What constitutes a severe earthquake, as the Committee uses that term, and of what degree of severity does it consider the earthquake of April 18th, 1906? Granting that earthquakes may be so severe as to wreck any class of structures, what degree of severity is to be provided for in the design of buildings?

It would seem that the Committee must define its position on these points in order to be fully understood.

Mr. Hindes. S. G. HINDES, M. AM. SOC. C. E. (by letter).—At the time of the earthquake the writer lived in an old house on Russian Hill, at the corner of Green and Leavenworth Streets. The house was built in 1860, and withstood the earthquakes of 1862 and 1868 without damage. The walls are entirely of concrete, 12 in. in thickness throughout their entire height, and rest directly on the solid rock. Four years ago, in making two large openings through the original walls, one laborer was able to cut a doorway in about two days, thus showing that the concrete had very little strength, there being probably very little cement used in it. Although the earthquake was not as severe on Russian Hill as in lower parts of the city, it was severe enough to unhook pictures and throw them across the room, but these walls were practically uninjured. The inside plaster was somewhat cracked, but the walls themselves are apparently unhurt. There is no reinforcement whatever in the walls.

Mr. Hunt. LOREN E. HUNT, ASSOC. M. AM. SOC. C. E. (by letter).—The writer desires to call attention to a few notable examples of brick construction which successfully withstood the earthquake shocks about a year ago. All San Francisco engineers are familiar with the buildings and will agree that they represent good brick construction. They are the older Federal buildings in San Francisco. The "Appraisers Building" suffered practically no damage. The "Mint" was less damaged than the modern steel Post Office two blocks away. Most remarkable, however, is the case of the old Government building now known as the "Sailors Home," which was condemned as "unsafe" thirty years ago, and yet came through the disaster practically unharmed. It is not affirmed that good construction is the only reason that these brick buildings are still standing, but good construction was certainly an important factor. Their preservation is a tribute to the care and efficiency of the Government engineers.

Mr. Duryea. EDWIN DURYEA, JR., M. AM. SOC. C. E. (by letter).—The concrete pumping-pit of the Palo Alto municipal water-works, about 50 ft. deep, was at first thought to be undamaged by the earthquake, as no cracks were visible in the walls. Later, however, it was found that where the well-casing entered the base of the pit, the joint had been broken by the earthquake so that whenever the pump (a centrifugal

pump placed on the bottom of the pit) was stopped, the pit rapidly filled with water nearly to the ground surface. Largely on account of the crowded condition of the pit and the interference of the work at the base of the pump, etc., the expenditure for repairs was about $1 300. Mr. Duryea.

BERNARD BIENENFELD, M. AM. SOC. C. E. (by letter).—In the earthquake countries of the Far East, it is the practice, as elsewhere, when putting up substantial buildings, to go down to solid material, preferably rock, for foundations. The overlying loose material, or earth, is thereafter cut away and kept clear from contact with the foundation walls. It is the excessive motion and jelly-like tremors in the loose earth that cause the greatest damage in an earthquake shock. By thus avoiding contact between the comparatively incoherent superficial earth and the walls of the building, the vibration is minimized. It would be well to follow this practice in San Francisco. This might necessitate the use of curb or slight retaining walls to confine the loose earth, and such walls, both in their footings and on their faces, should be separated from the main building walls. Such a construction would add somewhat to the expense of construction; but the additional first cost would be a very cheap and efficient insurance against future disaster. Mr. B. Bienenfeld.

Regarding the contention of the Committee that the ordinary brick construction is inelastic, observation of the action of the brick walls of wrecked buildings that were being torn down subsequent to the earthquake and fire would indicate that there is indeed a considerable and surprising internal elasticity in this form of construction. Wherever good work had been done, and where the foundation was firm, brick buildings passed the ordeal of the shock remarkably well.

It is undoubtedly true that a proper reinforced-concrete construction on a proper foundation is among the forms best calculated to resist earthquake shocks; but it is none the less evident that a properly founded and constructed brick building has earthquake-resisting features considerably greater than the Committee has indicated.

It is to be deeply regretted, however, that the class of brickwork now being done in the rehabilitation of the city is generally of a nature to invite serious disaster in future severe earthquakes. The throttling restrictions of the labor unions, and the indifference and incompetence of the municipal building authorities are particularly blameworthy.

J. P. CARLIN, ASSOC. M. AM. SOC. C. E. (by letter).—Concerning the reviews and discussions of the conclusions reached by the Committees of the San Francisco Association, the writer is glad to note the unanimity of opinion, regarding the criticism of the Mr. Carlin.

Mr Carlin. Committees' finding, with special reference to brick construction on the San Francisco Peninsula. The following conclusion was reached by the Committee:

"It may be stated, as one of the most obvious lessons of the earthquake, that brick walls, or walls of brick faced with stone, when without an interior frame of steel, are hopelessly inadequate."

This was not at all obvious to the writer, when he examined the ruins, and, he believes, is not the fact.

In determining the damage to any of the wrecked buildings, careful investigation was required in order to ascertain what proportion was due to the fire and what to the earthquake. The civic pride of the people of the ill-fated city prompted them to attribute nearly all the destruction to the fire, and consequently their opinion must be discounted for bias. On the other hand, it would seem that many visiting committees have reported upon the ultimate damage as they found it, and have failed to consider properly the earthquake damage independently of the fire.

The vigilance committee in San Francisco, or "Committee of Safety," organized immediately after the fire, used heroic measures in leveling the ruins; and, naturally, the buildings to suffer most were those since brought under the ban of the beforementioned Committee. Dynamite was used unsparingly, especially in razing unsupported brick walls, wherein fires had completely gutted the interior because they were not of steel frame or so-called fire-proof construction. Consequently, there are, or were, but few cases in which buildings of brick exterior walls were left standing; but, such as did remain are classic examples of slow-burning construction in championing the cause of brick buildings in San Francisco when properly built.

The writer made a personal examination and report on the ruins of the Palace Hotel, and with special reference to reconstructing it without razing the existing walls. This structure covered an entire block, in area about 250 by 300 ft., was seven stories high, and was of brick throughout. Along the Market and New Montgomery Street façades, there were iron columns with supporting girders for sprandrel-wall construction up to the second-floor level, and there were interior steel girders supported on brick walls; but, in no sense was the building a steel-frame interior, for the interior walls throughout were of common brick.

This building—the largest brick hotel in the world—was almost uninjured by the earthquake, excepting for a few minor cracks, but was, of course, completely gutted subsequently by the fire. An examination of the ruins showed that the brick walls were in excellent shape—straight as to alignment, and without other fracture than was obviously caused by the fire—and the construction was

unimpaired at all the salient points of the building. The bonding, at the corners and at the points where the interior walls intersected each other or the main walls, was perfect; and this fact is mentioned especially because, in all steel-frame structures, with brick exteriors, the bonding of the front wall to the side walls was almost invariably cracked. Mr. Carlin.

Many of the steel-skeleton buildings were branded by Nature's condemnation marks, in the shape of *X*-cracks, about midway of the height. These were due to the flexibility of the structure, thus permitting the foundations to move coincidently with the shock and before the superstructure; and, being followed by the latter, in an effort to regain equilibrium, produced great stresses about the middle third.

The Foljer Building, on Howard Street, was of brick exterior and wood interior, and was left standing after the earthquake, the fire not having reached it. As was generally the case in buildings of any description, the chimneys suffered and a small portion of the parapet wall, but otherwise the building was not damaged; and yet, at this very site, the street in front of the building had settled about 2 ft. The California Electrical Works Building, on Folsom Street, was of similar construction, and, barring the usual roof disturbance, no damage was done by the shock.

The foregoing is positively and negatively in favor of ordinary brick buildings. It seems to the writer that a most important point with reference to building construction in earthquake countries has not been emphasized sufficiently, or has failed utterly of consideration, and that is to treat the subject as a problem akin to one of buoyancy in water, and, in the design of building construction, to apply the principles of flotation. A familiar example of lack of stability in marine architecture is, of course, a small craft of little draft or beam in a heavy sea. To obtain rigidity, the displacement of a craft is increased, and, for this purpose, lead is added to her keel. Now, the undulating action of an earthquake is not unlike ordinary wave action, and should be treated in the same way. If, therefore, the foundations are designed so as to be sufficiently heavy, and are made a unit, with reference to the superstructure, the building will either safely ride the earthquake wave, or, if the superstructure is not of flexible construction, it will move with the foundations, just as a ship does, and as a unit.

The Post Office Building well illustrates the necessity for unified foundations. This building was on piles, and was located in the Mission District, which is to a great extent "made land." Although the structure was of heavy construction, it was practically supported on stilts, and the earthquake wave motion moved through this forest foundation, following and developing lines of

Mr. Carlin. least resistance, with consequent promiscuous racking all over the building. At the four corners the cracks were most pronounced, exactly at the angle where the heavier portions of the building joined the lighter contiguous connections. These four flanking corners were on unit pile foundations, as regards themselves, and moved independently with reference to the remainder of the building. Had this entire building been piled uniformly, and—more important still—had the foundation been capped with a solid layer of concrete over the entire site, and of sufficient thickness and depth to make the resulting mass a unit, it is believed that the structure would have withstood the shock, and would have ridden safely the petrified waves, which now appear so clearly in the immediate vicinity of this building.

In recent years, it was necessary to design a special method of foundations to meet the soil conditions in Chicago. This consisted of steel grillage embedded in concrete, and was called the "Chicago method," or "floating foundation." This, of course, has been superseded by caissons carried to rock.

It seems to the writer that San Francisco, in its reconstruction, will be forced to accept the "floating method" of foundation where it cannot reach bed-rock economically with a unified foundation, and that it should also use a rigid type of superstructure. Obviously, this will be obtained best by heavy masonry construction, like that of which the Palace Hotel structure was a type. These suggestions are not advanced on the score of either economy of space or of construction, but they seem to be best adapted as methods of building construction in regions of seismic disturbance.

Mr. Goad. CHARLES E. GOAD, M. AM. SOC. C. E. (by letter).—Conflagrations seem to be prevalent chiefly in that portion of the North American Continent inhabited by the Anglo-Saxon race, mainly owing to the "inordinate greed of immediate gain" that characterizes the construction of rapidly growing centers of population.

There are from 5 000 to 6 000 cities, towns and villages, in the United States and Canada, in continual danger of being swept by fire; thus it would seem reasonable that the question of the "Best Means for the Prevention of Conflagrations" should have serious consideration by all persons interested in the welfare of the community.

This subject is worthy of the attention of the American Society of Civil Engineers. Statistics, easily obtainable, show that the fire wastes by conflagrations (besides those caused by ordinary isolated fires) are appalling. More than 1 000 000 buildings in 10 years, says one authority; in 39 years (1866 to 1904) more than $542 000 000 of fire waste in conflagrations alone.

How often have we, who know these dangers, walked through the

congested districts of our principal cities and towns, wondering why they still existed; and, on seeing "fire-traps" and "sources of danger" being hurriedly run up, do we not frequently wish for a dictator's power to stop such rash and foolish construction? Mr. Goad.

The natural foes to be met by civil engineers are taken to be water and decay. Fire, usually considered as a servant, should be regarded with more attention as a possible enemy. After a serious conflagration, there always ensues a period of "proposed amendments and improvements," all too soon forgotten when the temporary panic has ceased.

The chief "physical" preventions to the spread of conflagration may be summarized as:

1.—Impervious walls and fire-resisting construction;
2.—Wide, and open spaces;
3.—Abundance of water, concentrated at the proper place, at the right moment.

The chief "moral" preventive is:

To have officials (more than one) with knowledge of how to act, and with authority sufficient to obtain immediate organized help.

Impervious Walls.—Much can be done by insisting that, in certain districts well known as liable to conflagration hazard, some walls should be constructed so as to prove a barrier to a fire that has become temporarily beyond control.

There is one good wall in the heart of London City that has already to its credit the stay of conflagrations in five instances, and the members of the fire brigade hail with delight the aid of their "old friend," when a fierce fire meets it again.

The London County Council is gradually introducing by-laws making improvements in this direction, and there is a tendency among municipal authorities to consider these matters on a more comprehensive scale.

Not only vertical, but also horizontal, fire-breaks are worthy of attention. Since the Cripplegate fire (London, November, 1897), building acts have been amended so that every alternate floor in that district must now be fire-resisting.

In the old City of Stamboul, the Turkish part of Constantinople, two stone walls, 40 ft. high, have been erected in the "Lumber District," and more are needed.

The European suburb, across the Bosphorus, Kadi-Keui, consisting mainly of buildings of wooden construction, appears to have laws which compel the construction of a brick wall, without openings, on one side of a wooden building. While it looks curious, and somewhat absurd to a chance visitor, to see a dead brick wall

Mr. Goad. on one side of a wooden building, with nothing but vacant fields for 500 ft. distant, yet had such a law been enforced in communities of wooden structures on this Continent, before buildings became grouped in closely congested areas, the aid to the prevention of conflagrations would be obvious.

Wide, Open Spaces.—After every conflagration, efforts are made to increase the width of streets, and to open wide, new thoroughfares, but, as a rule, "vested interests" prove too apathetic, and nothing is accomplished.

After the Great Fire of London (September, 1666) Sir Christopher Wren urged the construction of wide thoroughfares, and prepared a plan, the adoption of which would have been of immense benefit; but he was too far in advance of his age, and his plans were not carried out.

St. John's and Carbonear, Newfoundland, are instances where "fire-breaks" of great width, but of too limited an extent, were adopted after serious fires.

Our forefathers in New England and in the Maritime Provinces usually managed to allow sufficient space between wooden buildings in order to prevent conflagrations; but now-a-days the greed for immediate gain is such that fire-traps are allowed to be run up in close proximity to each other, and the danger is overlooked, or, if considered, is merely inadequately guarded against by fire insurance.

It would be well within the powers of hundreds of towns and villages that are springing up all over the country, to forbid the erection of wooden buildings within 50 ft. of one another, until such time as proper fire-resisting walls were built to intervene between them. The same rule should apply to suburbs of cities consisting of wooden buildings, wide thoroughfares being made wherever practicable, the widening of all principal streets being encouraged, even if at an apparently extraordinary expense.

Dynamiting Buildings.—This method is considered to be poor policy in staying a conflagration, as the shattered, disintegrated mass is the more easily ignited, and windows, hundreds of yards away, are blown in, affording ready access to burning embers.

Abundance of Water.—A lesson to be learned from the record of nearly every conflagration is, that the control of the water supply should be such that, in time of need, certain sections could be supplemented by an increased volume of water, and that it should be practicable to cut off each section in which the firemen have been driven from the hydrants without having had time to close them.

The old-fashioned system of underground water cisterns had many advantages, though, where water-works have been installed, these cisterns have generally been abandoned as unnecessary. In

the case of failure of water systems through earthquake, accident, or malicious interference, however, the supply from cisterns would be an important factor in the fight against a sweeping conflagration. Mr. Goad.

Ponds, or small artificial lakes, in central squares, while beautifying the city or town, would also serve a useful purpose in times of conflagration. A small quantity of water judiciously used can be made to accomplish great results; this is known from actual experience.

The "Moral Preventive."—The moral preventive is to prepare for war in times of peace—to have men trained to meet a disaster—not merely one chief, who (as in many instances of late) may be incapacitated by accident, or who may be absent, but several. These men should be trained to work together, and should have a thorough knowledge of the water systems and of possible fire-breaks; they should be always in readiness to take action at the time, instead of, as is now too often the case, each one acting in such a manner as to retard the efforts of the others by want of knowledge and lack of previous instructions.

The managers of fire insurance companies frequently do good work in preventing conflagrations, though they are usually roundly abused for increasing the rates; they would deserve commendation if they not only would raise the rates, but would also make them prohibitive, or if they would decline to insure in districts which seem designed to foster the spread of conflagrations. This is now actually done by some managers, yet the majority will still accept such risks, and assist in the continuance of careless and "tinderbox" construction.

The British Fire Prevention Committee, founded in 1897, composed of architects, civil engineers, district surveyors, etc., in Great Britain, is doing valuable work in inculcating better methods of construction, with special reference to resistance to the spread of fire; its reports (now numbering 120) of fire tests, and of matters pertaining to this subject, will be of interest and service to students of fire resistance.

The National Fire Protection Association, including fifty "underwriters' organizations and engineering bodies," is doing good work on similar lines on this Continent.

The reports of the Committee of Twenty of the National Board of Fire Underwriters are valuable documents, serving to show where danger exists, and how to combat it.

While it must be acknowledged that no drastic methods of reconstruction of "congested-centers" will be tolerated by a community at the present time, yet there is hope that, by calling especial attention to impending dangers, and, by submitting remedies

Mr. Goad. at every favorable opportunity, much can be done to educate the people in the science of safeguarding their homes against destruction by conflagration.

Mr. Green. R. B. GREEN, M. AM. SOC. C. E. (by letter).—The failure of the water supply for fire protection having led to a fire loss which far exceeded that from shock, it is interesting to note the respective reports of the three Committees on Water-Works, Lighting and Street Railway Transportation, and Sewers.

The first states that pipe lines and conduits, of any character whatever, are almost certain to fail when intersected by a plane of large movement; the second, that "The underground conduit system and the Edison tubing came through both earthquake and fire in very good shape;" and the third, that sewers on rocky ground ·ere uninjured, while those on made land were wrecked, but all the wrecked sewers were old brick ones, the joints of which were of sand in place of mortar; and recommends reinforced concrete sewers. In the search for all possible emergency aids, it would seem that deep trunk sewers might furnish a supply of water for a fire-engine's suction when all regular water supplies are crippled. Every manhole would be a possible suction well.

A shock that would cripple a water main under pressure might break a trunk sewer, but would probably not choke it so as to prevent ground-water from coming down and back-water from backing up from the outlet, unless there should be a tidal wave, such as would cripple even a fire-boat service. Back-water often extends in trunk sewers up through the low-level business sections of water-front cities, and could be had in new sewers by dropping a small portion of the invert below outlet level. A brick intake main extending back through the lower parts of a town would be similar, but more costly. Similarly, sewers in higher districts, known to have large inflows of ground-water, might also furnish a certain amount of aid in extreme emergencies. Bags of sand, to dam a small flow, or drop-sumps would aid in the smaller sewers.

Gates or temporary dams at the outlets of large sewers would aid in backing their flow up to the higher levels distant from the harbor front. This effect would be aided by having the fire-boats pump into the sewers after their outlets were closed.

Another aid would be obtained by having special fire protection piping in suitable piping subways. This piping, if loosely hung or laid through the subways, might pass through a shock that would cripple a pipe rigidly buried; or, if broken, would be immediately accessible in the subway and could be repaired quickly by special sleeves. This piping could be connected to the fire-boats or to special auxiliary pumping stations near the water edge.

C. E. MOORE, M. AM. SOC. C. E. (by letter).—The writer has been deeply interested in earthquake strains for several years, and, in the design of structures, he has endeavored, as far as possible, to provide for such strains. Some years ago the matter was taken up and reference was made to such reports as were available, these being mainly derived from experience in Japan. In general, it has been assumed that the strains were caused by lateral motion only, and that the vertical component was too small to be taken into account. As a rule, this is no doubt true, and the general correctness of the report of the Committee regarding the absence of vertical movement in the earthquake of April 18th is not questioned. However, from observations made by the writer, it seems to be clear that there must have been some vertical movement within a limited area in the Santa Clara Valley. As far as observed by him, the district in which this movement seems to be indicated is not more than 1 mile wide and 10 miles long. In that area there were some instances which appeared to indicate an upward impulse of a very decided nature. Mr. Moore.

Out of many cases, four have been selected as typical, and are included here:

First.—One of these is the manner of failure of the water tower at Santa Clara, which is described in the Report of the Committee on Water-Works Structures. It may be repeated here that two tanks were thrown off, and the remaining two were moved fully 20 ft. on the floor of the tower before falling. There can be no doubt of this, as it was seen by several witnesses, and it is indicated by the subsequent position of the tanks and columns. It is hardly conceivable, to one who is familiar with the situation, that this movement could have been caused entirely by sliding.

Second.—At Mountain View, at the other extremity of the area above alluded to, a timber structure was destroyed in a manner apparently similar. At Palo Alto, a few miles farther to the northwest, a structure of exactly similar construction, and about 25 ft. higher, was uninjured.

Third.—At the Santa Clara College, a large weather vane on one of the buildings has a shaft about 4 in. square. This stood in a cast-iron socket 12 in. deep, making a fairly close fit. This shaft was thrown out of the socket, neither being broken.

Fourth.—At the Catholic Cemetery at Santa Clara, a monument about 8 ft. high, the large end being 12 in. square, rested upon a base 4 ft. high. It was secured to the base by a brass pin $\frac{5}{8}$ in. in diameter. The monument proper was thrown off the base, turned completely over, and laid with the top end next to the base and the large end (or bottom) away from it. The brass pin stood vertically 7 in. above the base, and was not bent. At the Protestant Cem-

Mr. Moore. etery, half a mile farther west, no such effects were produced, although several monuments were thrown down. At the County Hospital, a mile to the south, and on somewhat higher ground, the buildings were practically destroyed, but a steel structure carrying water tanks, which was erected by the writer several years ago, was uninjured. A large quantity of water was thrown out, as the tanks were nearly full, but they did not move from the floor. In their construction, there was no reason for this which did not exist also at Santa Clara and Mountain View.

At Agnews' Insane Asylum, 2½ miles north of Santa Clara, and on lower ground, near the marshes of San Francisco Bay, there was, as stated in the Report of the Committee on Water-Works Structures, a structure similar to that at Santa Clara, which was uninjured. The tanks were empty at the time, so that probably no valuable conclusion can be drawn from this fact. However, the Committee on Fire and Earthquake Damage to Buildings reports no evidence of vertical movement there, and this was the conclusion reached independently by the writer.

The axis of the strip above referred to follows along the edge of the "Artesian belt," or "Lowlands," as it is known in the Santa Clara Valley. This line passes near the Mountain View Water-Works, the Santa Clara Water-Works, through College Park, and near the Hotel Vendôme, in the northern part of San José. By following this line and going not more than half a mile on either side, one could easily locate fifty badly wrecked frame buildings. At College Park there were many, all being near this line. West of the Alameda (about half a mile from the line indicated), there was not a single case of this kind. The writer is of the opinion that the Committee's statement, that "damage to buildings * * * was confined to those faulty either in design or in construction," should be modified, as regards this locality. These buildings could not be classed as "faulty." All through the country an occasional defective building was wrecked, but in this locality the list included many good buildings, and it is these to which reference is made.

The Hotel Vendôme (a well-built frame structure) was wrecked so badly that it has been practically rebuilt, and has only recently been opened. Many residences in that vicinity fared similarly, although, half a mile farther south, such buildings suffered comparatively little. From all this it seems that the effect varied greatly in different localities, and it is not safe to conclude that, because no evidence of vertical movement is found in certain buildings examined, such movement did not occur at other points. The variation with locality appears to have been recognized in countries where earthquakes have been frequent, as one writer says: "Certain

areas in earthquake localities have been marked off as unsuitable for any buildings." Mr. Moore.

It has seemed to the writer that the formation of the ground in these localities may explain, at least partly, this variation.

It would appear that any mathematical investigation of the waves would be impracticable and useless, on account of the great diversity in the character of the material passed through.

It appears, however, that the oscillations are transmitted from the seat of the disturbance by a wave movement, which must involve vertical motion, although possibly such motion may be very small. It appears also that this primary wave has a very long wave length, which renders the vertical component imperceptible. At Mount Hamilton (Lick Observatory), 20 miles to the east of Santa Clara, and at the summit of a rocky range, there was reported "no vertical movement."

At a small observatory at College Park, instruments were dismounted and no record was made. It seems, however, that, in certain localities, secondary waves are generated, and, as to magnitude and form, these depend upon the character of the ground traversed. At the Santa Clara Water-Works, there is, under a few feet of soil, a stratum of stiff yellow clay, underlaid by a stratum composed of sand and water, approaching quicksand in character. Rock is at an unknown depth, certainly as great as 1 200 ft. To the west, on higher ground, the clay stratum becomes deeper, being covered by from 30 to 50 ft. of mixed clay and gravel. The lower stratum is quite different in character, or is entirely absent.

At Agnews', the clay stratum is either absent or is covered by many feet of adobe. It appears, then, that the area referred to in the beginning is limited to a locality where a stiff clay is underlaid by a yielding stratum; and that secondary waves pertain chiefly to the surface, and do not affect the ground to any great depth.

It seems to the writer that a movement somewhat similar to that observed here may have occurred in other localities where the damage was greatest, for instance at Santa Rosa.

At Santa Clara, the first waves were from the southwest, but, before these ceased, they were crossed by waves from the northwest, these, as stated by Dr. Jordan, of Stanford University, being due to oscillations from more distant points along the fault line. The crossing of waves caused a twisting movement, by which many buildings were turned on their foundations, so that the two ends projected in opposite directions from the foundations to the extent of 2 or 3 in. This occurred with many frame houses, and in the case of certain large buildings in San José.

Referring to permanent vertical displacement, as distinguished from the vertical wave component, Dr. Jordan states that along

Mr. Moore. the fault line, at the summit of Black Mountain, there was a relative change of level amounting to 2 ft., indicating at that portion of the line either a rising of one side or a subsidence of the other. The presumption is, however, that this effect does not exist, to any appreciable extent, for any great distance from the fault line.

Mr. Himmelwright. A. L. A. Himmelwright, M. Am. Soc. C. E. (by letter).—The Report of the Committee on Fire and Earthquake Damage to Buildings was eagerly awaited by all who have to do with the construction of modern buildings.

The span of human life is short, and a disaster such as that which occurred in San Francisco will probably not be repeated in another century. The lessons which it taught, and especially the effect on fire-proof buildings, are of such vast importance that a critical, careful, and detailed investigation and report would have been a valuable contribution to our knowledge of building construction. It is to be regretted that all the photographs taken and collected by the Committee could not have been printed with the report, because such illustrations are frequently more satisfactory than verbal descriptions. It is also unfortunate that the Committee's report is so brief that, in many cases, it is necessary to indulge in general statements, which are entirely too broad, and to that extent are misleading. A detailed report which would have embraced twenty times the space taken by the Committee would have been welcomed gladly by the architectural and engineering professions.

In the design and construction of buildings of the better class, which are now made as nearly fire-proof as possible, architects and engineers are searching constantly for those materials and methods which will show the best efficiency and fulfill the purpose for which they are intended. Definite and exact information on this subject is what is desired particularly. The behavior of any given material under varying conditions, or of the same material used in different ways, would supply information of the kind sought. The fact that all materials are damaged more or less when exposed to intense heat does not interest the designer; but the fact that one material proved more efficient than another, under the same conditions, is valuable information. Instead of collecting information of this character, the Committee seems to have made an effort to generalize and classify results, which practically nullifies the usefulness of the report.

There are in the report a few statements of facts which are somewhat at variance with the writer's observations. On page 322* a statement is made that the Bush Street front of the Mills Building leaned toward the street from 7 to 9 in. Careful determination,

* *Proceedings*, Am. Soc. C. E., for March, 1907.

made under the writer's direction, in the latter part of May, 1906, showed that this front leaned out toward the street only from 4 to 5 in. Mr. Himmelwright.

The very severe condemnation of masonry-walled structures without steel frames is a little unwarranted. Where the walls were tied together and the masonwork was executed with good Portland cement mortar, neither the earthquake nor the fire caused any serious damage. The Palace Hotel and the Parrott Estate Building, at the northwest corner of California and Montgomery Streets, are two noteworthy examples of brick and stone masonry without interior steel frames which stood the test with very little structural damage.

The writer takes decided issue with the Committee on the general statement, on page 329,* that "all materials were destroyed when directly exposed to the fire for any length of time." While it is admitted, by those thoroughly informed on this subject, that the different building materials have varying relative values, from a fire-resisting standpoint, it is now an established fact that there are materials capable of resisting in a thoroughly satisfactory manner, and with inappreciable damage to the material itself, any exposures to flames and heat which are likely to occur in any large conflagration. This is an important fact which should have been defined clearly in the report.

In considering the subject of the material for fire-proof floors, only two kinds are mentioned, namely, terra cotta and concrete, and the statement is correctly made that, of these two materials, "terra cotta suffered the more"; also that, "in all cases the record of concrete is better than that of tile." No distinction, however, is made between different kinds of concrete and tile and different forms in which they were used. There is a vast difference in the fire-resisting qualities of concretes made from different aggregates, and in the case of the same aggregates used in different ways. There is also a difference in the fire-resisting qualities of hollow-tile blocks.

The writer has made an extended study of the fire-resisting qualities of different materials used for fire-proofing purposes, not only in San Francisco and Baltimore, but also by full-sized, practical fire and water tests which have been made at different times under his direction. It is well known that stone concrete, whether the aggregates be of granite, sandstone, limestone, or trap rock, suffers from dehydration when exposed to heat, and for that reason is less desirable as a fire-proofing material than concrete made from aggregates which do not contain "water of crystallization." It has been demonstrated that stone concrete, when exposed to a temperature of from 1 800 to 2 000° fahr., for a period of 4 hours, will be affected

* *Proceedings*, Am. Soc. C. E., for March, 1907.

Mr. Himmelwright. by dehydration to a depth of from 3 to 4 in., and the strength of the concrete will be seriously impaired to that depth. When the concrete has been damaged by dehydration, the aggregates break and disintegrate, and the bond between the aggregates and the cementing material is lost, so that an ordinary fire-stream, under 60 lb. pressure, will easily abrade the under surface, and wash it away. If the concrete is allowed to cool after being heated, and without the application of water, the dehydrated surfaces can be picked apart by the fingers, or easily removed with a small tack hammer, to the depth to which dehydration has taken place. All natural rock contains moisture, and for that reason concrete made from any variety of stone aggregates will be dehydrated when subjected to heat, and consequently is unsuited and poorly adapted for use as a fire-proofing material in any position where it is likely to be subjected to high temperatures.

The fundamental principle in a concrete for fire-proofing purposes is the use of aggregates which do not contain moisture, but which, when made into concrete, possess sufficient strength to fulfill the requirements. Steam-boiler cinders, crushed furnace slag, crushed brick, and "tetzlonti" (a light, porous, lava rock occurring in the vicinity of the City of Mexico) are the materials best suited for fire-resisting concretes which have been found to be commercially available. Concrete made from these materials, with very little ramming, to secure lightness and porosity, has been shown to possess excellent and satisfactory fire-resisting qualities.

Another important feature of a concrete which is to resist heat is the presence of voids. A "full concrete" in which the voids are filled solidly with cementing material is desirable from the standpoint of strength, but this feature detracts very largely from its fire-resisting qualities. The ordinary requirements for strength in building construction, where these materials are used for fire-proofing purposes, are amply fulfilled by a concrete which possesses a large percentage of voids, so that their presence is a decided advantage in ordinary fire-proof floor construction.

The different forms and the principles involved in the construction of concrete floors have also an important bearing on the efficiency and fire-resisting qualities of the different methods. In all recent large conflagrations, the segmental arch, in which all the material is used in compression, and in which the strength is independent of light metal elements, proved to be in a class by itself, and developed fire-resisting qualities and strength vastly superior to any of the flat-slab methods in which light steel reinforcing elements were used in tension.

In all the flat-slab methods in which steel tensile elements are used the economical position of the reinforcing metal is invariably near

the under surface of the slab, and as far away as possible from the neutral axis. When located in this position, the nearer it is to the under surface of the slab, the more it is exposed to the effect of the heat when attacked by fire; and, when thus exposed, the reinforcing metal has very little value as a load-sustaining portion of the construction. Mr. Himmelwright.

When the reinforcing metal is covered with 1 in. of stone concrete, which is the maximum thickness of covering usually provided, experiments show that the metal is heated to a temperature of about 800° fahr. in about 1 hour, and to 1 300° in from 3 to 4 hours, when subjected to a uniform temperature of 1 800° fahr. At 800° fahr. reinforcing steel loses approximately 26% of its strength, and at 1 300° its strength is practically nil.

The flat-slab methods in which steel is used in tension are, for the above reasons, vastly inferior, for horizontal-load sustaining construction, to the segmental arch methods. In wall and partition work the use of metal reinforcement near the center of the section is much less objectionable, as the metal elements act largely as stiffening and bracing members, and the slab, being in a vertical plane, sustains its own weight and is therefore less likely to be deflected and damaged when subjected to heat.

The most elaborate and instructive fire and water tests ever made were conducted by the New York Building Department in 1896 and 1897, under the direction of Mr. Gus. C. Henning. These tests were made scientifically, and are on record in the Department. A brief *résumé* of three of these tests will be interesting in connection with this discussion. On December 23d, 1896, a stone-concrete, flat-slab, floor section, 11 by 15 ft., was tested by fire and water. The concrete floor was supported by two steel beams at about 4-ft. centers. The reinforcing metal consisted of bars at 16-in. centers, the under side of the bar being about $\frac{5}{8}$ in. from the under surface of the concrete floor slab; the section of the bar was $\frac{1}{4}$ in. by 2 in., the 2-in. dimension being vertical. The concrete was mixed in the proportion of 1 bbl. of Dyckerhoff Portland cement, $2\frac{1}{2}$ bbl. of sand and 5 bbl. of small broken blue stone passing a sieve of 1-in. mesh, with 12.8% of water in bulk. Rock wall plaster, mixed in the proportions prescribed by the manufacturers, was then applied to the under side of the flooring to a depth of about $\frac{3}{8}$ in. A second coat of this plaster was applied later, making the total thickness of the plaster from $\frac{1}{2}$ to $\frac{5}{8}$ in. A white finish was then applied in the usual manner, representing the usual conditions in finished buildings. This floor formed the roof of the test structure built for the purpose, and was located about 10 ft. above a grate, of the same area as the floor, on which a hardwood fire was maintained to produce the temperatures. The fire was started at 10.30 A. M.,

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and the following temperatures (as recorded by a Uhling and Steinbart pyrometer) were produced at the times set opposite:

Time.	Temperature, in degrees, Fahrenheit.	Time.	Temperature, in degrees, Fahrenheit.
11.13 A. M.	1 775	2.00 P. M.	1 950
11.30 "	1 850	2.40 "	2 100
12.00 M.	2 050	3.00 "	2 200
12.30 P. M.	2 000	3.30 "	2 100
1.12 P. M.	2 100		

At 3.30 P. M., while the ceiling was observed to be in a red-hot condition, water, at a pressure of 60 lb., was applied to it with a fire-hose having a regular 1⅛-in. nozzle. Some of the plaster had fallen away previously, and the remainder was washed away by the water. The fire-stream also abraded the entire under surface of the stone concrete flooring to a depth of 1¾ in., wherever the water struck it, exposing all the reinforcing bars to an average of about one-half their depth.

The abrasion of the concrete to the depth stated was due, no doubt, primarily, to dehydration of the stone, and secondly to rupture and disintegration caused by the sudden cooling while highly heated, on the application of the fire-stream.

A similar fire and water test was made on a flat-slab, cinder-concrete floor on April 23d, 1907. The concrete consisted of 1 bbl. of Atlas Portland cement, 2 bbl. of clean, sharp sand, and 4 bbl. of steam-boiler cinders. The reinforcement consisted of 2½ by 6-in. mesh expanded metal of No. 10 gauge. This was laid directly on the centering, and the concrete was deposited over it to a depth of 4 in. The plaster was King's Windsor cement, applied in accordance with the manufacturers' specifications, in two coats, to a total thicknes of about ½ in., approximating to the same condition as in the test previously mentioned. The fire test was started at 10.05 A. M., and at the following times the corresponding temperatures were obtained:

Time.	Temperature, in degrees, Fahrenheit.	Time.	Temperature, in degrees, Fahrenheit.
10.52 A. M.	1 800	1.12 P. M.	2 000
11.30 "	2 200	1.40 "	2 100
11.58 "	1 900	2.30 "	2 050
12.06 P. M.	2 100		

At 3.05 P. M., water, at a pressure of 60 lb., was applied to the ceiling with a fire-hose having a regular 1⅛-in. nozzle, while the under side of the flooring was observed to be in a red-hot condition. Wherever the water struck the ceiling the plaster was washed off,

but only a very small quantity of the cinder concrete was abraded, barely enough to loosen in spots the expanded metal fabric, the under side of which was flush with the bottom of the slab. Mr. Himmelwright.

A similar test was made of a segmental, cinder-concrete arch on October 28th, 1906. The concrete was mixed in the proportions of 1 part Aalborg (Danish) Portland cement, 2 parts clean, sharp sand, 5 parts steam-boiler cinders, without screening or washing, and as taken from the chutes of the New York Steam Company, and 1.35 parts water. This concrete was laid on a permanent wire centering consisting of No. 19, four-warp, two filling wire-cloth, stiffened by $\frac{7}{16}$-in. round steel rods woven in at intervals of 9 in., segmental in form, providing for a thickness of about $3\frac{1}{2}$ in. at the crown of the arch, the concrete being placed in position without ramming and by simply patting and smoothing the top surface with shovels. The plastering consisted of ordinary lime mortar furnished by the United States Mortar Supply Company, of New York City, and the two coats aggregated $\frac{5}{8}$ in. in thickness. One entire bay, or one-third of the under side of the floor area, was left unplastered so as to expose the concrete to the direct action of the flames. The fire test was started at 10.06 A. M., and the following temperatures were obtained at the times set opposite:

Time.	Temperature, in degrees, Fahrenheit.	Time.	Temperature, in degrees, Fahrenheit.
11.14 A. M.	1 700	1.06 P. M.	2 100
11.35 "	1 900	1.45 "	2 050
11.55 "	2 050	1.57 "	2 125
12.16 P. M.	2 000	2.18 "	2 130
12.30 "	2 150	2.55 "	1 950
12.43 "	2 300		

At 3.06 P. M., water, at a pressure of 60 lb., was applied to the ceiling with a fire-hose having a $1\frac{1}{8}$-in. nozzle, while the under side of the flooring was observed to be in a red-hot condition. The following is quoted from records of the Building Department:

"Close examination of the concrete showed that the wire netting had been completely burned off in the naked arch. The concrete arch (unplastered) seemed not affected in any way by the fire or water except small spots washed away where water struck with great force."

The spots referred to were not more than $\frac{1}{4}$ in. in depth, and did not aggregate more than 3 sq. ft. of the entire surface.

Several months after this test was made, two 2-in. cubes, made from the concrete which had passed through this test, were tested for strength, and developed a crushing strength of 940 lb. per sq. in., which shows about the same strength as a similar normal concrete

Mr. Himmelwright. of the same age, and indicates therefore that, with the exception of a very thin layer at the actual surface of contact with the flames, the concrete was uninjured by the test.

Approximately 1½ hours were required in all these tests to develop a temperature of 2 000° fahr. This minimum temperature, with a maximum temperature running up to 2 500° fahr., was maintained for about 3½ hours longer before the application of water.

In the special structures used for these tests, the walls were of brick, 13 in. in thickness, with four flues at each corner. The intake openings below the grate were sufficiently large to induce the necessary draft, and this was regulated by sheet-iron dampers. To produce and maintain the temperatures recorded, an average of about 7 cords of hardwood fuel was consumed, representing a total average depth of approximately 5½ ft. over the entire grate area.

In the average office and hotel building, the combustible contents, which would be consumed in the case of a conflagration, consist of the wood finish, the furniture and the furnishings. If these were all removed and placed in a layer of uniform thickness over the floor area, there would seldom be an average depth of more than 6 or 8 in.; or, approximately, one-tenth of the quantity of fuel consumed in the New York Building Department tests. The intensity of the heat and the duration of the fire in the interior of fire-proof buildings depend upon the conditions of draft and the quantity and character of the fuel or combustible contents. In the San Francisco hotels and office buildings the average duration of the fire in any one room seldom exceeded 20 or 30 min. In special cases, as in supply and storage rooms, the duration of the fire was longer, but the conditions of draft in rooms of that kind were generally such that the fire smouldered and did not burn with as intense a heat. The average maximum temperatures attained in these buildings, as determined by the fusing of metals and other phenomena, ranged from 1 500 to 1 900° fahr. In certain spots where there happened to be more than the average quantity of fuel, and the conditions of draft were favorable, temperatures up to 2 100 and 2 200° fahr. were sometimes reached. These maximum temperatures, however, were not maintained for more than a few minutes in each case.

From the foregoing observations, and on account of the total quantity of fuel that it was possible to consume, it should be apparent, even to an inexperienced person, that the test by fire during the conflagration in the average hotel and office building in San Francisco was comparatively light, and approximately only one-eighth to one-tenth as severe as the regulation fire test made by the New York Building Department. The effect of the fire on the fire-proofing materials, as observed by the writer, was approximately in this proportion. It is patent, therefore, that nowhere near the en-

durance of good fire-proofing material is ever reached in buildings of this class. Mr. Himmelwright.

There were certain structures, of course, such as the Kamm Building, the Sloan Building, and others, in which large quantities of combustible materials were stored. There were also certain rooms and limited areas in other buildings where larger quantities of combustible materials were stored, greatly increasing the duration of the exposure to fire. There were, however, no cases observed by the writer which were exposed to as severe a fire test as the standard tests of the New York Building Department in 1896 and 1897. There were places where a fire burned continuously for from 24 to 36 hours, but the conditions of draft in those cases were not favorable for the production of high temperatures over any considerable areas, and consequently the actual damage to the concrete fire-proofing was not as great as might have been expected. The greatest depth to which dehydration extended, in the most extreme cases observed, did not exceed 1½ in.; while the observations on cinder concrete did not disclose any damage whatever. The last remarks refer, of course, to concrete which was of good quality previous to the fire.

In San Francisco, stone concrete was used for floor construction and fire-proofing more generally than any other. Gravel, steam-boiler cinders and broken brick were also used as aggregates to a lesser extent. Cinders are not used more generally in San Francisco because the ferries and railroads, and some of the power plants, use oil instead of coal as a fuel, and comparatively few cinders are available. There were, however, a number of buildings in which cinder concrete had been used.

In the basement and cellar stories, the metal lath and plaster ceilings were generally omitted, thus exposing the under side of the concrete floors covered with plaster directly to the flames. Generally speaking, there were larger quantities of inflammable materials in the basement stories than in any of the others, and consequently the fire-proof floors directly above were generally exposed to a longer attack of heat than those of the upper stories. Then, again, there were instances, such as in the cases of the Aronson, Young, Scott, and Sloan Buildings, and others, in which there were no metal lath ceilings, or which had such ceilings only in one or two stories. In these buildings, and in the basement stories of others, there was ample opportunity for a careful and intelligent comparison between the fire-resisting qualities of stone and cinder concrete, as well as the relative effects of fire upon the segmental-arch methods and the flat-slab methods, in which steel reinforcing metal was used in tension. There are always sufficient phenomena, such as the fusing of metals, the effect on plaster, brick and stone work, the quantity

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of ashes, etc., etc., from which it is possible to glean a very good idea of the duration and intensity of the heat generated. The inexperienced investigator, however, is very likely to be led to erroneous conclusions by superficial observation. In both Baltimore and San Francisco there were buildings in which the concrete fire-proofing appeared to be damaged considerably by the fire, and many intelligent architects and engineers were misled by the appearance of these concretes after the fire. Very few took the time and trouble to seek out a spot where the material had been subjected to very little or no heat and examine the material to ascertain its actual condition before the fire. Wherever concrete fire-proofing has been apparently damaged by a normal attack of fire, such as could be expected in a hotel or office building, the writer has invariably found, on close investigation, that the concrete was of poor quality, and that this fact has been thoroughly disclosed and emphasized by the fire.

The conclusions arrived at by the writer as to the relative fire-resisting qualities of the different materials used for fire-proof floors are set forth in considerable detail in his report on the disaster, entitled, "The San Francisco Earthquake and Fire, 1906," a copy of which is in the Library of the Society. These may be briefly stated as follows:

The segmental cinder-concrete arch, in short spans (8 ft. or less), where the concrete was originally of good quality, developed the best fire-resisting qualities and strength. This material and this form of using it proved vastly superior to any other used for fire-proofing purposes. This method was used in the Hotel St. Francis, and in the ground floor of Haas' Candy Factory, at the corner of Mint Avenue and Jessop Street, and not a single square foot of the floor arching in these buildings was damaged in the least by the fire.

The next best fire-resistance was shown by the short-span (8 ft. or less), cinder-concrete, flat-slab floor construction, in which steel reinforcing metal was used in tension. This method and material was used in the Merchants' Exchange, in which the damage by fire was inappreciable.

The next in order of fire-resistance was the same short-span, flat-slab method of reinforced concrete in which stone and gravel aggregates were used. This method and material was used quite extensively, the best results having been shown in the Mutual Savings Bank Building, the Bush Street and South Offices of the Pacific States Telephone Company, and many others.

The next method in the order of fire-resistance was the reinforced stone-concrete construction proper in long spans, and where rolled-steel girders and beams were generally omitted. Where this method was used, a very slight attack of fire was generally sufficient

to cause the rupture of the concrete underneath the reinforcing metal, so that it fell away, exposing the metal. There were comparatively few buildings, however, in which this method of construction was used. Mr. Himmelwright.

The material which gave the least satisfactory results, from a fire-resisting standpoint, was the hollow tile blocks, whether used as end or side construction.

In many of the hotels and office buildings a separate, flat, metal lath and plaster ceiling was erected underneath the fire-proof floors, which is in itself a fire-resisting barrier of considerable value, and a protection that must be taken into consideration in the economical design of fire-proof construction. A well-designed and executed metal lath and plaster ceiling remained in position intact in a New York Building Department test for a period of 4 hours from the time of starting the fire test. This represented a period of 1½ hours during which the temperature was raised from 70 to 1 700° fahr., ½ hour from 1 700 to 2 000°, and 2 hours during which the temperature ranged from 2 000 to 2 300°, averaging, approximately, 2 100° fahr. This ceiling was suspended by clamps or hangers made from steel stock weighing ½ lb. per lin. ft., hooked around both sides of the lower flanges of the beams, at 16-in. intervals; it supported approximately 7 sq. ft. of ceiling surface per hanger. The furring consisted of flat bars weighing 0.6 lb. per lin. ft., set on edge and running through slots in the hangers. The metal lath was stiffened with ¼-in. round steel rods at intervals of 7½ in., and was laced to the furring bars with No. 18 galvanized-steel lacing wire at every intersection of the stiffening rods with the furring bars. These details are important, and are given in order to describe the essential features of a metal lath and plaster ceiling which will give good efficiency. In hotels and office buildings, a ceiling of this character will afford ample protection for the soffits of the floor beams, making it unnecessary to cover these separately with an additional fire-proofing material. This fact also results in a saving in the thickness of the floor construction, and for this reason is an economical feature.

A fact that was demonstrated convincingly in the San Francisco fire was the undesirability of copper wire for fastening metal lath, the much lower fusing point of copper in numerous cases permitting the metal lath to drop away from the supports long before it would have failed had steel wire been used. This fact was particularly noticeable in the James Flood Building and in the rooms damaged by fire in the United States Post Office Building. It has been the uniform practice in the Supervising Architect's Office, during the last 10 years, to specify copper lacing wire for fastening metal lath in all the Government buildings. The ceilings in these buildings,

Mr. Himmelwright. therefore, cannot be expected to develop the best fire resistance in case of an actual test.

The report of the Committee tends to create erroneous impressions as to the province of metal lath and plaster ceilings, and states that in many cases they protected the concrete floors. While this is true to the extent of their value as a fire-resisting barrier, the concrete floors, when composed of good material, were sufficiently refractory to have made a good record without the ceilings referred to. In the case of the hollow tile blocks, however, where these were protected only by plaster, in nearly every case the soffit members of the tile blocks were cracked away, exposing the cellular spaces. The very general damage of this character indicated that this material possesses poor fire-resisting qualities. Wherever well-constructed metal lath and plaster ceilings were erected under tile blocks, as in the James Flood Building, and in the upper stories of the Spring Valley Building, they prevented serious damage to the blocks. This was demonstrated clearly by the fact that wherever the metal lath and plaster ceilings fell away in spots, the tile blocks directly above were in all cases badly damaged. The tile blocks also showed great weakness and inability to resist the impact of falling bodies on account of brittleness, and numerous safes in the various office buildings very generally fell through the tile floors into the basement, breaking holes through the successive floors under them and sometimes inflicting serious damage to the mechanical plants.

On page 334* of the report the following statement is made:

"The fire shows that a cover of lath and plaster directly upon the flange, protected again by the suspended ceilings, is the best. The layer of plaster alone on the flange will not protect."

In view of what precedes it, this statement, which is typical and characteristic of the report, illustrates the difficulty in arriving at general conclusions. A metal lath and plaster soffit protection is well known to be less efficient than 2 in. of cinder concrete, held in place by metal lath, with plaster applied over that. The efficiency of the metal lath and plaster ceilings and their field of usefulness as fire-resisting barriers, have already been discussed. An actual misstatement, however, is made in the latter part of the above quotation, in that there were several notable instances where a metal lath and plaster soffit protection gave exceedingly good and satisfactory results, namely, in the Kamm Building and the Aronson Building. In both of these buildings crimped or corrugated wire lath was wrapped around the soffits of the beams, the corrugations offsetting the wire surfaces about ¾ in. from the beam. This lath was placed in position before the concrete was laid, so that the

* *Proceedings*, Am. Soc. C. E., for March, 1907.

edges were thoroughly anchored in the concrete. After the removal of the wood forms, plaster gauged with Portland cement was applied to the soffits, filling the spaces between the metal lath and the beams solidly with the material and making a total thickness of approximately 1 in. of cement plaster protection. There were no metal lath and plaster ceilings underneath the soffit protection, and in the Kamm Building this method was subjected to as severe a fire as occurred in any of the fire-proof buildings in San Francisco, yet a careful examination of the building immediately after the fire did not show any failure whatever of this soffit protection. The same method was used with good results in the Aronson Building, where it was exposed directly to the flames without any intervening metal lath and plaster ceilings. Mr. Himmelwright.

The report of the Committee goes somewhat into detail in recommending certain methods of fire-proofing columns and other important structural members. While the recommendations given are excellent for certain conditions, the treatment of columns, like fire-proof floor construction, is a question of economical adaptation to the requirements.

The protection to the steel frame, as well as the method used in the floor construction, must in all cases be adapted to the character of the building and the quantity of its combustible contents. A building with floors finished in cement, marble, or other incombustible material, with metal-covered woodwork and only a small quantity of combustible furniture and furnishings, will not require as heavy and efficient protection for the steel skeleton frame as a warehouse, department store, or similar building in which will be stored large quantities of combustible goods and materials. A standard or uniform method of protecting structural members, to be used in all classes of buildings, would not be economical, and would result in a hardship and waste in many cases.

An important fact, which is of interest to architects and engineers, and to which the report of the Committee does not refer, relates to architectural terra cotta. When properly designed, and set in a first-class manner, the results were generally satisfactory. In many cases, however, where the cores were large and the shells of the material were less than 2 in. in thickness, it spalled and cracked under moderate heat.

Another important lesson taught with great emphasis by the San Francisco disaster was the necessity of avoiding all forms of block partitions around stairway and elevator openings. These generally proved to be weak, both in the earthquake and in the fire, and almost invariably failed. The débris from such enclosing partitions fell upon the stairways, frequently breaking them down and causing irreparable damage. The failure of the block partitions also precipitated large quantities of blocks into elevator

Mr. Himmelwright.

shafts, damaging the framework and doors, and often injuring large portions of the mechanical equipment in the lower story. A reinforced-concrete partition with vertical steel members anchored to the beams, or fire-proof construction at the top and bottom, is vastly superior and preferable for enclosing openings of this character.

The writer is greatly surprised at the statement made by the Committee in its final conclusions on page 333* to the effect, "that the destruction of fire-proofing must be expected, and that it will have to be restored after a fire."

There is absolutely no question that, at the present time, methods and materials are available for fire-proofing purposes which are thoroughly efficient and will fulfill the various requirements for different classes of buildings in an entirely satisfactory manner. By this is meant that when suitable methods and materials are used and adapted intelligently to the requirements of any particular building, such fire-proofing will not be damaged seriously by the combustion of the inflammable contents of the building in the case of a fire. The efficiency of first-class methods and materials has been demonstrated in full-sized fire and water tests made at different times in the past, and numerous examples of entirely satisfactory fire-proofing were to be found in both the Baltimore and San Francisco conflagrations.

To reach correct and intelligent conclusions, and make definite progress in the development of fire-proof construction, it is necessary to exercise intelligent discrimination and adopt that which is good and which has proven efficient in actual test by fire; and discard and abandon that which has failed or proved deficient. This principle was followed by the writer in his report, already referred to. By giving complete, detailed descriptions of the methods and materials of construction in the instances of satisfactory fire-proofing, some of which have been referred to in the report, such as the concrete column protection in the St. Francis Hotel, the Shreve Building, and others, and the fire-proof floor construction in those buildings where good results were shown, definite information would have been available to assist architects, engineers, and others in designing efficient fire-proof construction for future buildings. Unfortunately, the report of the Committee is absolutely devoid of such detailed information, and an exceptional opportunity for rendering a public service has thus been lost.

There is, finally, a phase of this subject which has not yet been touched upon—the commercial side. The writer's long experience in the business of contracting for fire-proof construction has afforded exceptional opportunity to study the attitude of capitalists, owners, and architects on this subject. It will no doubt be a sur-

* *Proceedings*, Am. Soc. C. E., for March, 1907.

prise to many to learn that in more than 95% of the fire-proof buildings erected during the last five years the mistaken economy of owners and their representatives has prevented the adoption of good fire-proof construction in that proportion of buildings. In every case the difference between a poor and mediocre method of fire-proofing and a first-class and efficient method has not been in excess of from 2 to 4% of the cost of the building. As long as a cheap method or system of fire-proofing complies with the building laws of the city in which the building is to be located, and fulfills the requirements for strength, the average owner is satisfied, and is unwilling to appropriate any additional money whatever for superior methods or materials. It is the same old story of "just as good" substitution. Mr. Himmelwright.

When the owner, as is generally the case, has no practical knowledge of building construction, and is incapable of judging of the merits of different methods and materials, he invariably adopts the lowest-priced method or system offered, or instructs his architects or representatives to do so. One of the incomprehensible things is the further fact that the average owner, or his business representative, thinks that he is fulfilling every moral and business obligation by offering to award the work to the concerns furnishing first-class and efficient methods at the same price that the poorest and cheapest methods are offered to them. This policy and method of placing contracts for fire-proof construction is used almost without exception, even by large railroads and wealthy corporations.

In the case of all other building materials, such as stone, brick, steel, cement, etc., quality is carefully considered, and the prices are graded accordingly; but in the consideration and selection of fire-proof construction, which is probably the most important detail of a modern building, quality and efficiency have been entirely neglected up to the present time.

As long as owners and architects are unwilling to pay the small additional amount necessary to secure first-class fire-proofing they must expect results such as were shown in Baltimore and San Francisco whenever a conflagration of any magnitude occurs. It would seem, however, that the exercise of the most ordinary intelligence would prompt the owner of a valuable building to expend from 2 to 4% of its cost, in order to secure exemption from damage to the structural parts of the building, and an additional 5% for the protection of exterior window and door openings, in order to save the contents of the building from exterior attack by fire.

It is to be hoped that the recent great disasters in Baltimore and San Francisco will serve to show the great importance of recognizing merit and quality in fire-proofing methods and materials, and demonstrate the necessity, as well as the ultimate economy, of using first-class and efficient methods of fire-proofing in future buildings.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

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PAPERS AND DISCUSSIONS.

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THE REINFORCED CONCRETE BRIDGE ACROSS THE HUDSON RIVER AT SANDY HILL, NEW YORK.

Discussion.*

By Messrs. Henry H. Quimby, C. L. Slocum, D. L. Krellwitz and E. W. Stern.

Mr. Quimby. Henry H. Quimby, M. Am. Soc. C. E. (by letter).—This bridge is an interesting illustration of the economic and æsthetic advantages of concrete as a material of construction. A steel-girder structure with paved deck would have cost more—the $72 000 would scarcely have paid for the superstructure alone—and the cost of proper maintenance capitalized would add a very considerable percentage to the total. Its appearance—its architecture—is also very pleasing, and the bridge will be a lasting delight to the community served by it.

The paper, while presenting the novel features and discussing the important points of the design, is somewhat meager in respect to several matters in which designers of concrete arches are especially interested. The stress diagram, and the method used in computing the stresses in the steel and concrete, including the temperature stresses, would add much to the value of the paper, as would also the details of the cost—the quantities and unit costs of the several divisions of the work.

* This discussion (of the paper by William H. Burr, M. Am. Soc. C. E., printed in *Proceedings* for April, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

The advantage of locality, of the proximity of the raw materials, may have been considerable, but, even then, the management must have been very efficient, for the cost of the work seems to have been quite low and the time consumed remarkably short. Mr. Quimby.

The stresses in the arch due to changes of temperature will be high at the crown and at the spring, the whole effect of the change in length of arch, and the consequent rise and fall of the crown, being concentrated at these three points because the intermediate stretches are held rigidly to shape by the spandrel walls, unless the latter should be ruptured. The author's analysis of this effect would be valuable. The paper states that the bridge is designed to carry the specified loads without exceeding a compressive stress of 500 lb. per sq. in. in the concrete, and that, for all ordinary loadings, even with the prescribed railway loads, that compressive stress does not exceed about 400 lb. per sq. in. It is not clear whether the difference between the two represents the temperature stress, or whether the higher is merely the extreme fiber stress at the greatest eccentricity of the center of pressure.

The order in which the concrete was placed is an important consideration. If the soffit sheathing, in which was embedded the rods anchoring the block-built outer ribs to the inner ribs, was not constructed at the time of grouting the blocks, an opening between the blocks and the sheathing is possible, thus admitting water and subjecting the anchors to corrosion and ultimate destruction. The method of placing the rib concrete and that of the walls affects the question of initial stresses in the material, which, when combined with temperature stresses, are undoubtedly sometimes the cause of spalling and cracking.

The transverse reinforcement of the interior spandrel walls is novel, and will probably not be generally regarded as necessary. The cleavage that such reinforcement will resist is only longitudinal, either vertical as a spilt or diagonal as a shear of a column in compression, and such thin walls should not be subject to the former, and these are stressed so low vertically that the latter should not be feared. A very efficient reinforcement in the same direction would be flat stones embedded horizontally in the walls. This is found to add to the compressive strength of the concrete, and also to be economical, for the extra labor of placing is more than offset by the saving of cement concrete.

The channel sleepers under the track rails seem to be merely bedded on the concrete. If they are not bolted down firmly they will be likely to give trouble by loosening and pounding. It has been found necessary in this class of track construction to hold the rails down firmly to a solid bearing on the concrete to prevent chattering, thus pulverizing the surface and corrugating the rails.

Mr. Quimby. The wisdom of the plan of construction—block facing built up several courses and then grouted, and afterward filling in the heart with concrete which pretty certainly will shrink away from the facing—will not be generally conceded. Shrinkage openings, as well as the almost inevitable voids that the grout will fail to fill because of entrapped air and other stoppages of flow, will be likely to collect water, which is a destructive agent in all masonry; and the claim made in the paper that the construction is monolithic is hardly warranted. The economy of the method is open to question, which, however, should be answerable by the record of cost on this work compared with the fairly definitely known cost of wooden forms. The other expressed purpose of the adoption of this system of construction—to produce a satisfactory surface finish—could have been easily accomplished in monolithic work by removing the face forms within a day or two of placing the concrete and then scrubbing off the film from the surface, leaving the aggregate exposed to view. The result of this treatment is a face which is stone-like in texture and wearing quality, and not subject to the discoloration which mars a cement surface; or the face might have been tooled to remove the film, thus obtaining a surface which would be quite pleasing.

Mr. Slocum. C. L. Slocum, Assoc. M. Am. Soc. C. E. (by letter).—The somewhat novel methods of design and construction used by the author, in this bridge, are of especial interest to the profession. The method followed in making each arch or series of arches independent and self-supporting, without leaving the falsework in place until the completion of the abutments, or providing an abutment support or its equivalent to withstand the dead-load thrust of the completed arch spans, has many distinct advantages, particularly in places where of necessity only a portion of the bridge can be built at one time. This is especially true where a series of arches span railroad tracks in constant use, and where all the room desired is not to be had.

Such conditions have been encountered in New Haven, Conn., in the construction of the arches of the reinforced concrete highway bridges of the New Haven Improvement of the New York, New Haven and Hartford Railroad. Here each highway bridge consists of four or five solid spandrel arches, each arch spanning a pair of tracks. In this improvement, in which the tracks are in a depression or cut, other recourse could not be had; there was not enough room to shift traffic from the site of the new structures, and besides, these highway bridges are so close to one another that certain spans in four of the five bridges of this class, have to be constructed to receive the tracks for traffic before the remaining spans can be completed.

REINFORCED CONCRETE HIGHWAY BRIDGE OVER TRACKS OF THE NEW YORK, NEW HAVEN AND HARTFORD RAILROAD.

Mr. Slocum.

The writer is of the opinion that, in most cases, fabricated units, or firm steel skeletons, are preferable to a less firm framework of rods and ties for reinforcement, especially in this and similar cases. In this particular construction, the fabricated units are made of old rails held together as rigid frames by old fish-plates and bolts, and bent-plates and bolts; longitudinal and transverse rods and vertical ties form a secondary meshwork between the built-up frames. In the design of this reinforcement, the writer, in addition to providing enough steel in the piers to take up the bending of the thrust at the springing line, giving an independent arch, has gone a step further. The frames of old rails are spaced so that, if it had been necessary, the usual kind of falsework, which is being used as a conservative measure, could be omitted, the lagging being hung from or attached firmly to the rail reinforcement. In other words, it is entirely feasible to erect these arches over tracks which are in constant use. Some European engineers, in design and construction, make the frame reinforcement large enough and strong enough to carry the requisite lagging and adjuncts. It is not at all improbable, in particular cases, that the saving in the cost of forms is greater than the increased cost of the added steel area required for self-support.

The general and detailed features of this construction have been described more fully in the technical press; however, by explaining the photograph, Plate LXXIV, perhaps what has already been stated will be better understood. The present main-line tracks at the extreme left of the photograph occupy the space necessary for the last arch and abutment. The arches are 31 ft. in the clear; the solid piers are plumb, and 2 ft. thick at the springing line. The last pier to which the remaining arch span is to be constructed is notched or cut out at the springing line to receive the last span. It is 12 in. thick at this point. The arch rail frames project out from this notch, and are connected to the vertical rail reinforcement which occupies the center of the pier. One side of this vertical rail reinforcement above the notch is barely covered with concrete, and the edges of the flanges of the rails are exposed in several places. There are frequent rabbets and other additional projecting rods of the meshwork to provide a good bond for the connection of the last arch. In addition to its own weight, this bridge, as shown in Plate LXXIV, has a temporary 7-ft. enclosed sidewalk which, during the noon hour, is quite congested with people from the nearby factories, etc. The main-line tracks are nearby, and although there is the usual tremor caused by trains passing frequently, there are no signs of weakness at this critical point, and none are expected.

Mr. Krellwitz.

D. W. KRELLWITZ, JUN. AM. SOC. C. E.—Professor Burr has given a most interesting description of this bridge, which is re-

Mr. Krellwitz. markable for its block construction. The architecture rendered by such block construction is very good when one considers the small sum of money expended for beauty and strength combined. The details and sizes are of considerable interest, and show clearly a good design. The speaker would like to ask what the deflections were at the crown of each of the fifteen spans when the centering had been removed?

Mr. Stern. E. W. STERN, M. AM. SOC. C. E.—Would Professor Burr be so kind as to state how the thrust of one of the arches would be provided for, if the adjoining arch were removed?

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WATER SUPPLY.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"Is it better policy to purchase and control water-sheds, thereby preventing the pollution of impounding reservoir supplies, or to suffer a certain amount of pollution of such supplies, relying upon filtration to correct the effects thereof?"

BY MESSRS. GEORGE W. FULLER, F. HERBERT SNOW, D. D. CLARKE AND GEORGE A. SOPER.

GEORGE W. FULLER, M. AM. SOC. C. E. (by letter).—Various local conditions require consideration, in deciding this question. This is particularly true as to the quality of water which it is desired to obtain, which quality must meet, or ought to meet, certain rational requirements of local or State health authorities. Mr. Fuller.

It is undoubtedly true that water supplies which were believed to be good 10 years ago are not in all cases now regarded as satisfactory in quality. As to water supplies of good quality to-day, there are strong reasons for believing that some of them will not necessarily be thus regarded a few years hence. We are in a transitional stage as regards the quality of public water supplies. Advanced positions taken by various health authorities and by public opinion, without doubt, now make it urgent for the engineer to be keenly alive to sanitary requirements, in order that public water supply projects may keep abreast of the times.

* Further discussion, had at the Convention, will be published subsequently, and additional written discussions are invited.

Mr. Fuller. The basic thoughts or premises should first be stated, in order to facilitate discussion, and, as they appear to the writer, they may be outlined briefly as follows:

1.—It is essential that the water from impounding reservoirs, or from any other source, shall be substantially free from disease-producing germs.

2.—A satisfactory public water supply should be of good appearance and free from objectionable quantities of mud, turbidity, and vegetable stain.

3.—A satisfactory water supply should be free from objectionable tastes and odors.

4.—Impounding reservoirs are of much assistance in the purification of water through natural agencies, as regards the removal of bacteria, turbidity, and peaty color. Their agencies are not infallible, and their efficiency varies much with different conditions as to rainfall, temperature, climate, storage period, and other physical factors.

5.—The elimination of pollution through the purchase of land is highly desirable, but in many places is prohibited by its cost. Sanitary control through inspection is helpful, but difficult of accomplishment under existing laws and customs.

6.—A well-designed and well-operated filter plant, with all its various appurtenances, such as efficient aeration, sedimentation, and coagulation, will allow a satisfactory water to be obtained from practically any impounded-water supply, although, within certain limits, the better the quality of the unfiltered water, the better and cheaper will be the filtered water.

Protection by Impounding Reservoirs from Disease Germs.—Where a reservoir has a capacity equal to the volume removed from it during a period of many weeks or months, it is obvious, from our present knowledge, that a large proportion of the disease germs will disappear from the flowing water. These germs have weight, and subside in fairly quiet water. According to laboratory experiences, disease germs live much longer in reservoir water than in sewage or highly polluted waters.

In all waters there is quite a rapid dying out of disease germs during the first week or so, and, with present laboratory methods, it is usually very difficult to detect the presence of any of these germs after they have been in water for two or three weeks. This does not prove, however, that all the germs have died out. On the contrary, the evidence seems to be quite strong that some of the more hardy ones, perhaps only a fraction of 1% of the total number, will survive for a long period, presumably months and years. Otherwise, it seems to be impossible to explain the continuance of water-borne diseases in certain districts.

While our knowledge of the passage of disease germs through large impounding reservoirs is by no means precise, our information is such that we cannot ignore certain physical conditions limiting the efficiency of the natural agencies there at work. Among such are the stirring up of the bottom layers of deep reservoirs, due to vertical circulation during each spring and autumn, and the effect of stratification and of various currents, which, under some conditions, no doubt bring the entering water to the outlet in an abnormally short period of time. Mr. Fuller.

It is futile to go into this subject in great detail here, but it is to be pointed out clearly that because a reservoir may hold 100 days' supply it by no means follows that the numbers of disease germs passing through the outlet are always as low as would result from the stay of these germs for 100 days in the reservoir water. Obviously, the protection from impounding reservoirs increases with the period of effective storage.

There are other factors also to be considered. Among them may be mentioned heavy rains, which sometimes wash into the impounding reservoir the accumulated filth of weeks and months, and also that such pollution may at intervals occur when the reservoirs are drawn down quite low, and when the opportunity for purification by natural agencies within the reservoirs is abnormally small.

Let us next turn to the question of how much pollution may suffice for impounding reservoir waters to produce disease among the consumers. The evidence is quite striking that the dejecta of one or two persons suffering from typhoid fever or other serious intestinal disorders may pollute surprisingly large volumes of water. This is particularly true when such dejecta accumulate during the winter months and are suddenly washed into the stream or reservoir when there is a general thaw. Experiences at Plymouth, Pa., New Haven, Conn., York, Pa., Scranton, Pa., and other places, show that the danger from a scattered population on the water-shed may at intervals be far greater than was considered possible a few years ago.

Notwithstanding its shortcomings, the impounding reservoir has been and continues to be a tower of strength in municipal sanitation in many places. This becomes quickly apparent upon comparing the typhoid death rate (about 20 per annum per 100 000 population) in New York, Newark, Jersey City, etc., which is as low as in numerous other cities more or less similarly situated, and having a public water supply either from underground sources or of filtered river water.

Filtration of upland water from sparsely populated areas, however, produces still lower death rates in some cases, as shown by the experiences of Paterson, N. J.

Mr. Fuller. Mortality statistics as to typhoid fever and other water-borne diseases are frequently only a very rough measure of the quality of a public water supply. This is particularly true of waters which are of fairly good character. Pollution may exist at times without its presence being recognized. This is probably true at intervals in the case of the Croton supply. Early in the spring of 1907 there was a small outbreak of typhoid fever in New York City, stated by Health Commissioner Darlington to have been caused by Croton water.

One of the weaknesses of the impounding reservoir is that its inefficiency cannot always be detected or corrected in time to avert danger. This accentuates the importance of more attention being given to one or both of the procedures advanced in this theme for discussion, namely: the prevention of pollution on the water-shed, or its correction by filtration.

Protection by Impounding Reservoirs from Unsatisfactory Physical Condition of Water.—Sedimentation in large impounding reservoirs usually produces sufficient clarification, and it is only at times of exceptionally heavy rainfall that the water is muddy when delivered to the consumers. As compared with the waters in large rivers, especially in the South and West, the impounded supply is quite satisfactory in this regard.

The remaining turbidity in the water drawn from an impounding reservoir, however, is usually due to very fine particles, dark in color, which produce what is called a "dirty appearance" in the water; this is frequently complained of much more than would be expected by the users of muddy river waters.

In the case of waters drawn from drainage areas containing more or less swampy tracts, the impounding of the water does much to bleach it by the aid of sunlight, and to lessen materially the brownish tint due to organic matter extracted from leaves and other vegetation.

It is with regard to tastes and odors that the most disagreeable physical conditions are likely to be encountered in the water of an impounding reservoir. These may be due to the decomposition of organic matter on the bottom of deep reservoirs, or to the growth and disintegration of various small forms of vegetable and plant life which make their appearance in reservoir waters in a more or less irregular fashion and in a manner not now fully understood.

The stripping of the bottom and sides of reservoirs does much in the early life of a reservoir to reduce the likelihood of bad tastes and odors due to vegetable growths. It is not an absolute safeguard against these troubles, however, and it is to be further pointed out that the effect of stripping is not wholly permanent in its nature. In fact, present evidence indicates that soil washings,

in course of time, perhaps 10 or 20 years, will largely obliterate the effect of stripping. Mr. Fuller.

When it is considered that a public water supply ought to be thoroughly "clean," it can hardly be maintained, in the light of modern requirements, that an ordinary impounding reservoir can give uniformly a thoroughly satisfactory supply in the absence of filtration, or of aeration, or of both.

It is true that swamps may be drained and various other expedients resorted to, but it is not ordinarily possible, in the opinion of the writer, fully to meet modern requirements as to the physical conditions of water through the agencies which act in the ordinary impounding reservoir. There are, of course, exceptions to this rule, and some exceptions will no doubt continue for a long time to come. The experiences and conclusions, however, at several places where bad tastes and odors prevail, show that, independent of pollution upon a water-shed, filtration is highly desirable and well worth its cost. The fact that trouble from microscopic growths has not yet been experienced in any given impounded supply is no proof that difficulties will not arise in the future.

Protection by Filtration.—For the most part, filtration has been practiced in America in connection with muddy and polluted river waters. For impounded water supplies, sand filters have been used successfully for two of the gravity supplies at Reading, Pa., the Ludlow supply at Springfield, Mass., and have been introduced recently at Bar Harbor, Me. Impounded water supplies have been treated satisfactorily by mechanical filtration at a number of places, among which may be mentioned Lexington, Ky., Middletown, N. Y., Norfolk, Va., and Charleston, S. C.

Available evidence shows clearly that by filtration a water can be made thoroughly satisfactory as to freedom from disease germs and objectionable tastes and odors, as well as of satisfactory appearance. Modern filter plants, both in their construction and their operation, require close adjustment to existing local conditions, and are bound to vary somewhat in their detailed arrangements. Filtration, in this discussion, is viewed in its broadest light, and with it is included efficient aeration and the use of coagulants when necessary.

As to the cost of filtration, that of an installation, complete, with all appurtenances, usually ranges from $15 000 to $30 000 per million gallons daily capacity. Usually, the figures for impounded reservoir waters would be nearer the lower figure, although there are special conditions in some places which require the higher figure to be exceeded. The cost of operating filters of moderate size usually ranges from $1.50 to $3.50 per million gallons for reservoir water, exclusive of pumping. Combining the operating expenses and capi-

Mr. Fuller. tal charges, taken at 5% per annum, there is obtained, for fairly representative conditions, the sum of $7 per million gallons. On the assumption that 100 gal. of water are used daily by each inhabitant, this would mean a total annual expense of about 25 cents for each inhabitant.

Filters ordinarily remove from 97 to 99.5% of the bacteria in the applied water. Where bacteria have been removed to a large extent by sedimentation in impounding reservoirs, the numbers are sometimes so low in the unfiltered water that the above percentages are not obtained. The residual number of bacteria, however, would be very low, and the water would be fully equivalent in hygienic quality to the above stated percentages of removal as we understand them in connection with practical operations in the filtration of river waters.

Filters are not germ-proof, and none of their warmest advocates claims them to be. Their efficiency has proved a tower of strength in municipal sanitation in the past—even greater than that of the impounding reservoir—notwithstanding the fact that a small fraction of the applied bacteria passed through the filters and appeared in the water supplied to the consumers.

Obviously, the more polluted the unfiltered water is, the less safe will be the filtered water. The logical question in connection with this discussion is this: To what extent can water-sheds be purchased and controlled, with the result that the water is made of thoroughly safe quality, and under conditions where the investment on the water-shed is preferable to an investment at a filter plant?

Two fundamental things are to be borne in mind: First, that, all things being equal, a pure water is better than a purified water; and, second, that by adjusting the rates of filtration, by double filtration, and by the use of germicides, it is perfectly practicable for [illegible] experts to deliver to the consumer almost any grade of [illegible] water that is wished, provided the purification works are [illegible] and operated strictly in accordance with the best available knowledge of sanitary science.

[illegible] and the re- [illegible] of water- [illegible] of filtration [illegible]

[illegible]—Data [illegible] estimate [illegible] difficult, how- [illegible] local con- [illegible] illustrative [illegible]

Mr. Fuller.

The total cost of efficient filtration may be taken at an average figure of about \$7 per million gallons per day, including interest, sinking fund, repairs, replacements, and operating expenses. This is equal to about \$2 500 per annum, corresponding to about \$50 000 as the sum required for the maintenance of filtration works of a capacity of 1 000 000 gal. daily in perpetuity.

A water-shed area corresponding to a dry-weather yield of 1 000 000 gal., of course, depends much upon the rainfall, the evaporation, the relative capacity and water surface of the impounding reservoirs, etc. For purposes of illustration, let us assume that 1 000 acres of water-shed area are required for the development of 1 000 000 gal. of water daily. This means that, for the purchase and control of water-sheds, there would be available about \$50 per acre, in order to have the cost of such treatment approximate that of filtration.

Where land is cheap, the water-shed area small, and the reservoir capacity large, there is merit in purchasing the entire land in some cases. For projects of moderate size, the writer believes that the likelihood of such purchase doing away permanently with the needs for filtration is too remote to be considered seriously.

Based on the above assumptions as to cost, it is seen that, for large water-sheds, where there are numerous villages, fertile farming lands, and desirable locations for country residences, it is hardly feasible to purchase the entire water-shed for anything like the sum which would permit efficient filtration to be maintained for all time.

If the costs were equal, and only one procedure were to be adopted, it is the writer's opinion that filtration would be preferable, not only on hygienic grounds, but for the sake of assuring a water supply of suitable physical character at all times.

In this it is to be borne in mind that filters have been installed recently at Bar Harbor, Me., notwithstanding the fact that there are no regular residents upon the water-shed, although it is stated that there are some three or four summer camps. Bad tastes and odors required the adoption of filtration.

As to the purchase of those lands upon which there are sources of objectionable pollution, and the control of the remainder by sanitary inspection, the writer is aware that this can be done with much benefit upon small water-sheds, but that it is frequently difficult to secure satisfactory results on large water-sheds by purchase and control.

The City of New York has undoubtedly benefited to a considerable degree by the elimination of objectionable sources of pollution upon the Croton water-shed, through the purchase of large numbers of small tracts of land, especially along the watercourses. However, the writer is keenly appreciative of the limitations to

Mr. Fuller. these methods as applied to the Croton water-shed of 360 sq. miles of drainage area.

Italian settlements on low, wet land may be purchased to-day, but they will certainly spring up again to-morrow in almost equally objectionable locations.

Sanitary inspectors may provide thoroughly sanitary arrangements for the removal of fecal discharges, but of what avail are they with a population whose habits are such that they will not use these sanitary conveniences, and whose lack of education is such that they persistently and regularly resist efforts to protect both themselves and the users of the water from the drainage area upon which they are resident?

Several things must be corrected before the purchase and control of water-sheds for large projects can approach the efficiency of filtration when conducted with moderate intelligence and skill as practiced in numerous places to-day.

A compaign of education is required, not only for the Italian on the Croton water-shed, but for many others whose views would no doubt respond to educational efforts to correct their ignorance and indifference. Such corrections will assume practical shape largely in proportion to the vigor with which wise sanitary laws are carried out promptly, and with a firm hand to administer proper punishment in an equitable manner, and about which there can be no dispute as to the division of responsibility between State departments of health, municipal departments of health, and municipal water departments.

The history of sanitary control of water-sheds in America, in the opinion of the writer, shows that it does not offer nearly the protection to the water consumer that is afforded by modern filtration. Sanitary control has been of great help in numerous places, but there are other instances where laws are inefficient, residents on the water-shed careless and indifferent, and where efficient results are more or less confined to the period when the inspector is actually on the premises. Better laws, better and larger organizations for sanitary inspection, and a better understanding by the residents of what is required can no doubt bring about improved results in the future.

While the writer is not in favor of sanitary control to the exclusion of filtration, he is clearly of the opinion that more stringent sanitary laws than now exist in most places should provide for the removal of all gross pollution, and that simple, practical methods should be gradually introduced to eliminate uniformly the lesser pollutions in the order of their importance.

Mention should be made of the reliability of filtration as actually carried out in practice. A decade ago many filter plants were such

in name only. The last few years have seen a marked change for the better. Practically all the larger filters are now well designed, and are arranged so that they can be controlled readily by intelligent, faithful attendants. Most important of all is the almost universal custom of installing laboratories at the filters, and of placing the operations under constant technical supervision. In no branch of sanitary engineering has more progress been made lately than in the efficient management of water filters for the larger cities. Mr. Fuller.

In the future, such management will certainly continue, as it will doubtless be obligatory to furnish frequent and full records of the results of operation to supervising State authorities.

Compared with sanitary inspection, scattered at different points over a water-shed, and in the hands of various individuals, it appears to the writer that there is far less likelihood of inefficiency in the operation of filters, centrally located, with the management under a single roof, and in the hands of a single person.

European Tendencies.—In Germany, where for a dozen years filtration has been practically compulsory for surface-water supplies, there are only a very few important cities which derive their water from impounding reservoirs. In Great Britain, however, there are many such supplies, and it is significant that the majority of the engineers having charge of new impounded-water supplies have provided not only for filtration, but also for the purchase of the water-shed, where this can be done at moderate cost. Fortunately, such purchase has been practicable, and has been carried out, at the new water-works of Liverpool, Birmingham, Swansea, Cardiff, Manchester, Edinburgh, etc. Land on these drainage areas is comparatively inexpensive, and the writer thinks that there is no room for doubt about the wisdom of eliminating at nominal cost all sources of pollution from a resident population.

There are various reasons why it is usually difficult in America both to filter and to purchase or control the water-shed, notwithstanding the desirability of doing both, from a theoretical standpoint. It is even necessary in some cases to install filters for polluted streams, when impounded-water supplies could be availed of as far as physical conditions are concerned. Under such circumstances, it is the writer's practice to arrange the filters so as to serve for the upland supply when financial and other conditions will permit its adoption.

Conclusions.—1.—The purchase and control of water-sheds is a less efficient procedure than filtration, as regards both the sanitary character of the water and its physical condition as to appearance, tastes, and odors.

2.—For projects of much magnitude, filtration is generally the cheaper.

Mr. Fuller. 3.—Sanitary control of a water-shed is of much assistance, but it is usually a difficult matter to manage well at all times for large water-sheds, under existing conditions as to sanitary laws, and as to the views and responsibility of rural population. Better laws are generally needed.

4.—The purification of water due to natural agencies in a large impounding reservoir makes its filtration easier, cheaper, and more effective than in the case of the ordinary river water. Purification plants can be installed to insure almost any degree of efficient purification that is desired.

5.—Notwithstanding the efficiency of filtration at reasonable cost, there is a growing tendency in America to provide as good sanitary conditions on a water-shed as practicable. As a rule, it is not believed that the purchase of the entire water-shed is advisable, on the ground that the money involved can be expended better in other ways.

Mr. Snow. F. Herbert Snow, M. Am. Soc. C. E. (by letter).—The sanitary conservation of public water supplies is a subject which forced itself upon the attention of the General Assembly of the State of Pennsylvania in 1905, resulting in the enactment of a law entitled "An act to preserve the purity of the waters of the State, for the protection of the public health," under which the Commissioner of Health is administering that branch of State medicine relative to public water-works and sewerage in a way to prevent ultimately a recurrence of epidemics of a water-borne character.

During the winter of 1906-07 three notable epidemics occurred in Pennsylvania, namely, at Scranton, Warren and Kittanning. Prior to this time the State had furnished the classic typhoid fever epidemic at Plymouth, and later at Butler. The facts in connection with these cases and the lessons they have taught should be clearly in the mind of the expert called upon to advise with respect to the amount of sewage pollution permissible on a water-shed.

The Scranton typhoid scourge came from an unfiltered surface supply of water derived from a mountain water-shed on which were located three villages and two railroads. The disease struck the town suddenly, lasted about 6 weeks, totaled over 1 000 cases and rolled up a record of over 100 deaths. No infection could be found on the water-shed. The poisoning of the water must have been accidental, but, nevertheless, it was certain. Typhoid bacilli were discovered in one of the reservoirs.

The lower basin, from which the gravity supply mains extend to the town, has a capacity of about 100 000 000 gal. The main impounding reservoir is 5 miles above, and has a capacity of over 1 000 000 000 gal. A short distance above is a third impounding reservoir having a capacity of about 400 000 000 gal. Extending for

several miles along and across the main stream, and by the shores of the three reservoirs, are the two railroads. Droppings from the passenger coach closets might easily have been washed from the roadbed into the city supply. Mr. Snow.

Although these and numerous other permanent menaces had existed on the water-shed for years, Scranton had never before been afflicted by a water-borne disease. Whatever pathogenic pollution had reached the reservoirs was either effectually destroyed by natural agencies or rendered impotent. Retention in the impounding basins must have been one of the formidable barriers against the entry of infection into the water pipe system. No doubt is entertained about such infection having been present in the city supplies prior to the epidemic. The topographical evidences are conclusive.

It was not due to improper operation of the water-works plant, or to any apparatus or appurtenance thereof, that the flood gates of disease were let down in this instance. Simply this: there came a day when all the natural barriers proved of no avail. Without any change in the physical conditions on the water-shed, and without warning, Nature's safeguards went down. What had proven for thirty years or more to have been an adequate plant for furnishing a pure and wholesome supply suddenly became inadequate, thereby transmitting disease and death to the community. The origin of the infection will probably never be known.

An intelligent mind cannot reflect on the history of this catastrophe without being impressed by the lesson it teaches. Barriers against water-borne diseases, to be effective under all conditions, should be capable of manipulation and control. The water company had purchased several hundred acres along the streams and around the reservoirs, and had attempted to control the water-shed by a system of patrols constantly maintained. Many nuisances were thus abated and some prosecutions made to prevent the pollution of the impounding reservoir supplies. During the epidemic, the State assumed control of the water-shed, and put in force rigid rules and regulations for the sanitary protection of the waters thereof. There are scores of public water-works systems to-day where the sources of supply are as likely to be infected, accidentally or otherwise, as the Scranton source, and even more so. Many human lives are bound to be sacrificed before adequate and universal preventive measures shall have been adopted.

At Warren, beginning on December 8th, 1906, an epidemic of gastro-enteritis raged for four days, during which 1 200 patients called for medical attention, and about 600 more were reported bedridden, but did not receive professional care.

This borough takes its water supply from driven wells, in the

Mr. Snow. town, on the banks of the Allegheny River, the waters of which are polluted by sewage. Investigations by the Department of Health pointed conclusively to the water as the medium of transmission of the poison. From the nature of the ailment, it was premised that the infection must have been in concentrated form.

The cause was discovered to have been the sudden rising of the river and the back-flooding of sewage through a drain pipe and ultimately through loosened joints of the piping of the driven-well system and into the town's supply. Attention to the sewer, which was in a leaky condition, and to the joints and packing of the suction pipes, which joints and packing had been loosened by alterations in the main suction pipe, would have prevented trouble. Too much care cannot be exercised with respect to the condition of the apparatus by which ground-water is obtained for a public supply, when such apparatus is located on the banks of a sewage-polluted river in which freshet heights inundate the surface of the land upon which the wells are located. The danger exists if there be sewage in the river, or a conduit, or a receptacle, or anywhere whence it may be transmitted to the drinking water. The lesson taught by this experience is that a ground-water supply, regularly proven by tests to be of superior quality, may suddenly become contaminated from a known remote source, and be prejudicial to the public health. The remedy, therefore, if it be practicable to do so, is to remove the remote danger, in other words, to pay attention to the proper disposal of sewage.

The sewers of Warren discharge into the Allegheny River about 90 miles above the borough of Kittanning, in which the source of public supply is the same river. The water was filtered, and was supposed to be purified. However, expert investigation revealed the fact that the plant had not been operated intelligently, nor was it equipped to render satisfactory treatment of the water possible. Yet the public was led to believe that the system of purification as installed and operated was a sufficient safeguard.

Several days after the Warren outbreak a similar epidemic of gastro-enteritis broke out in Kittanning. It lasted more than 8 weeks and numbered in that time upwards of 4 000 cases. The physicians of the borough reported that the vast majority of citizens were afflicted and received medical attention.

Pathogenic pollution from many municipalities on the banks of the river above Kittanning may arrive at the water-works intake at the latter place in condition capable of causing disease. The Warren infection might have been transmitted to Kittanning and have produced the epidemic there. The coincidence of outbreak in the two places attracts attention, although a local source of infection is more probable. But, besides the bowel trouble, there were

more than 100 cases of typhoid fever in Kittanning. This infection is believed to have been introduced through the medium of the river. Mr. Snow.

This case demonstrates how utterly inefficient may be the effort of those who, misinformed as to the essentials of water filtration, try to safeguard human life. Here was a water purification plant, installed for the purpose of preventing a recurrence of typhoid fever, totally inadequate to perform the service expected of it by the public, but, nevertheless, serving to foster a false sense of security.

In such a case, where the source is always dangerous, the interests of the public health demand competent design and skilled supervision of the construction of the purification works at first, and thereafter, capable management of its operation, and efficient maintenance.

The business of furnishing drinking water to the public is bound to be regulated by laws, passed to be enforced by central administrative power. The courts are beginning to give a different meaning to the words, so frequently appearing in water-works franchises, "pure and wholesome supply." Practical methods have been evolved whereby it is possible now to render water purer than it may be possible to obtain it in a raw state. The consumer is entitled to the kind of article he purchases, that is, a "pure and wholesome supply," and a Pennsylvania court has recently held that primitive methods of water purification, whereby a slightly better water than exists in the stream is furnished to the consumer, is not sufficient as long as that water is prejudicial to the public health.

The Butler epidemic, of the winter of 1903-04, affords a different lesson. At that place the public water supply was adequately filtered by a plant properly designed and operated. The source was from a rolling farming district, yielding turbid waters at times, and subject to possible sewage pollution. The filters had been installed to eliminate all danger and produce a clear water. This they did. The plant was one of the advertised assets of the borough; therefore, when the town woke up one day to the presence of considerable typhoid fever in the community, no one, not excepting even the newspapers (so alert usually to scrutinize critically a public utility plant), seriously suspected the water supply; and, remarkable to relate, not until 1 000 people were stricken and in bed was State aid called for and the true origin of the scourge discovered. The disease did not come in a day, but was cumulative.

The filter plant had undergone repairs just prior to the inception of the epidemic. During this period of repairs—several days—crude creek water was introduced into the street mains. There were several cases of typhoid fever on the water-shed, in a dwelling on the banks of the stream. The dejecta from the patients were

Mr. Snow. thrown out on the surface of the ground, where nothing prevented the poison from being washed into the creek, and hence within a few hours it arrived in the homes of the unsuspecting, confiding and wholly helpless water consumers.

Had the local or State health authorities been made aware of the first outbreak of the disease, or of the original cases on the water-shed, the history of the Butler epidemic might never have been written. But, as it was, 1 348 cases were recorded and 111 deaths.

This catastrophe produced one good result, namely, the establishment of the State Bureau of Vital Statistics. At present, physicians are required to send in morbidity reports. A repetition of the Butler case is not possible. That is, a community cannot be gradually attacked by typhoid. The onslaught must be sudden and sufficiently intense to cause the harm at once, because the officers of the local and State health departments are ever on the lookout, and report to the central office the first appearance of any infectious disease.

However, systems of reports can only apprise of danger. The poison may be disseminated through a water-works system in a few hours, and the first infection may take place before knowledge of it is possible. To the initial infection at Scranton should be attributed about all the cases there. Had the disease escaped detection in its early inception, the epidemic would undoubtedly have far exceeded the proportions it assumed, and thus might easily have gone down in history as the most appalling typhoid scourge on record. Thus the early discovery and the shutting off of the infected water in this one instance alone probably saved to the community, besides human life, a money consideration greater than the amount expended annually on records by the State and city Departments of Health.

In another instance, Johnstown, by the prompt report of typhoid on the water-shed, was saved from an epidemic under circumstances otherwise assuring a sweeping disaster. The poison was intercepted and killed, and not a case occurred in the town. Unquestionably, the morbidity reports instituted by the Commissioner of Health will repay to the public the cost of maintenance of the Bureau, and this work has been made necessary in following out the policy of preventing pollution of impounding reservoir and other surface supplies, as far as it is practicable to do so.

The Butler lesson teaches that an efficient filter plant is not an absolute safeguard; that as long as there is poison in the source, the danger of an explosion of disease of a water-borne character exists.

The Plymouth epidemic of 1885 attracted the attention of the world's sanitarians. The case was unique at that time. A town

Mr. Snow.

nestled at the foot of a mountain, furnished with a pure mountain water coming from an uninhabited water-shed—excepting one dwelling—was suddenly the scene of the terrible scourge of typhoid which numbered 1 104 cases and 114 deaths. The discovery of the origin was, for that day, a masterful work of detection, clear-cut and uncontroverted.

The owner of the single dwelling-house on the water-shed went to Philadelphia, contracted typhoid, came home, and was attended by a physician and nurse who did not know that the little stream at the foot of the bluff, on the edge of which stood the cottage, was the source of Plymouth's drinking water, and so they threw the poisonous stools out on the ground, where the dejecta remained frozen during the cold winter months; but in April, when the thaw and warm rains came, and the ice and snow all disappeared, the typhoid poison, along with everything else, was carried into the creek, and thence some of it found its way through the water pipes and into the town.

This was not the only supply to Plymouth. The Susquehanna River, receiving the sewage from Wilkes-Barre, 3 miles above, was used occasionally for parts of the town. This source was thought to be dangerous because it contained sewage, and suspicion had been directed to it for a long time. The public persisted in attributing the epidemic to the Susquehanna River water, until the proof of the true origin became conclusive. Although Wilkes-Barre's sewage constituted an immediate and always present menace, yet the citizens of Plymouth had not, prior to 1885, suffered from typhoid more than had other communities in the vicinity having sources of water supply which were not from the river. Contrary to the expectations of those interested in this case, came the proof that a constantly sewage-polluted river supply used by people who know the danger in the water, may not be as prejudicial to public health as a mountain supply free from pollution and having but one apparently insignificant menace upon the water-shed.

The disease held on through the summer months. Privy vaults abounded in the borough, also wells in close proximity thereto. People, mostly miners of foreign birth, would not heed the admonition to boil all water, and to disinfect all dejecta. Consequently, the wells were poisoned and the percentage of secondary infection was large.

The general lesson taught was startling and broad. Since one case of the disease imported could pollute the water supply of an entire town sufficiently to produce wholesale sickness and death, the officers of public and private corporations all over the country, were startled at the proposition that no municipality taking drinking water from surface sources is safe.

Mr. Snow. The conclusion reached at that time was that the individual in the village or rural district must dispose of his excrement in such a manner as not to pollute, directly or indirectly, any surface or well water.

The remedy was accepted as ideal, and impractical of accomplishment. To-day, with the aid of advanced methods of water and sewage purification, of public hygiene and municipal sanitation, a very much nearer approach to the ideal is practicable than in 1885. To this end the Pennsylvania State Department of Health was reorganized by the law of 1905, and the responsibility for progress in this branch of State medicine was placed in the hands of the Commissioner of Health.

The instances herein cited serve as a foundation for the enunciation of the principle that no unfiltered surface water, in any way likely to be polluted by sewage, is absolutely safe for drinking purposes. The risk attendant on the use of it may be slight. Where the risk is great, the life and health assurance afforded by filtration of the water is demanded as a public safeguard.

Still further, filtration is not an absolute safeguard, more especially when the source is subject to sewage pollution. The interests of the public health demand that sewage pollution of public supplies shall cease. Standards of excellence in the design, construction, and operation of water filter plants are first essentials to guard the public health, but this safeguard should not put a premium on the use of the watercourse as a sewer by some up-stream municipality. On the contrary, the original pollution of the water must be minimized.

A year ago the proper authorities of the three sovereign States—New York, New Jersey and Pennsylvania—met to formulate a policy of co-operation with respect to the sanitary conservation of inter-state streams and their tributaries. It was unanimously agreed that water filters were not alone sufficient, but that both water and sewage purification plants are demanded, in the interests of public health.

The right of eminent domain in Pennsylvania has been taken away from public water companies. It has been decided to be contrary to public policy to permit such companies to acquire thousands of acres of land for protective purposes. Further, it has been observed that purchase and control of large water-sheds does not necessarily prevent pollution.

A certain quantity of sewage is bound to find its way into the waters of most inhabited areas, but the legalizing of a certain amount of pollution of such waters, relying upon filtration to correct the effects thereof, is a dangerous expedient to practice generally. Start with the proposition that, after all is done that may

be done to keep sewage out of drinking water, the streams draining populous areas will still be unfit to use unless the water be filtered, and, using this as an argument against sewage purification works, grant licenses to towns to discharge sewage into the watercourses, and inevitably the pollutions must exceed the "certain amount." Mr. Snow.

The popular notion that it is permissible to discharge sewage into a stream which is not thereby made offensive to the sense of sight and smell is far from being dispelled. The local authorities of many towns are honestly dense with respect to this subject. It took an epidemic to teach the 1905 Board of Health of Nanticoke that the excrement of one individual could be transmitted many miles and kill those who drank the poison, although nothing might be visible in the water to indicate the danger. Yet Nanticoke is nearly opposite Plymouth. After the lapse of twenty years, the Plymouth lesson had to be repeated in the same district. It is not from the standpoint of nuisance, but from the standpoint of pathogenic pollution, that the campaign against putting sewage directly or indirectly into the waters of the State is being waged in Pennsylvania.

When the enormity of the crime of defiling water supplies appeals generally to everybody, there will be voluntary reforms. Meantime, the administration of law is a very pertinent matter. There is no public work of more importance to health than water purification and sewage disposal. Pennsylvania provides for central supervision of these utilities. No water-works or sewerage system can be legally extended or installed unless plans therefor have been submitted to and approved by the Commissioner of Health. Respecting the discharge of sewage, by a municipality, into any stream or body of water, the unanimous agreement of the Governor, Attorney-General, and Commissioner of Health is required. A penalty of $50 is provided for every day that a municipality pollutes illegally any of the waters of the State.

Dr. Charles B. Penrose, of Philadelphia, conceived the new State health laws, prepared the bills, and labored assiduously for their enactment. They are a worthy monument to a worthy man. The Honorable Samuel G. Dixon, who, as first Commissioner of Health, has had the task of organizing the new Department to put his conceptions of State medicine into operation, has inaugurated a policy which is bound to reduce water-borne diseases to a very large extent.

Every minor source of pollution on the water-sheds is to receive attention, and all menaces are to be permanently abated. Patrols by private and municipal corporations are to be required. The owner of each estate must cease to be careless about the disposal of sewage. Such disposal must be accomplished in a way unharm-

Mr. Snow. ful to others. Ordinary farm operations cannot be interfered with, but the effort is to confine pathogenic material within bounds. A health officer has been assigned to every municipality, to investigate, report, and execute orders.

Major pollutions, such as municipal sewerage systems, require more consideration. Often, the problem is one of finance. Slowly but surely the sewage of towns will cease to be discharged, untreated, into the waters of the State. First-class operation and maintenance of plants which have been constructed under State approval will be required. The necessity for State supervision is recognized, in fact, demanded. Without it, the "certain amount" of pollution of surface water supplies would be a large and dangerous amount, and the moneys, therefore, expended in the construction of sewage disposal works would be lost to a considerable extent.

Mr. Clarke. D. D. Clarke, M. Am. Soc. C. E. (by letter).—That the purity of the water supply of any city is a matter of vital importance is so generally recognized that it seems almost superfluous even to state the fact; but, when it comes to the question as to the best method of securing and maintaining the purity of the supply, there is a diversity of opinion. The writer holds that it is better to secure such a supply as shall be of unquestioned purity, rather than attempt the purification of waters known to be contaminated in the slightest degree; but it is recognized that the financial question involved is often a controlling factor, making necessary the adoption of methods which otherwise would not be approved.

As an illustration of what it is possible to accomplish, at least in the more recently settled portions of the continent, the writer would cite the case of Portland, Oregon, a city of 150 000 inhabitants, which secures an abundant supply of pure water from an absolutely uninhabited water-shed situated on the western slope of the Cascade Mountains from 30 to 50 miles distant from the city.

The advantage of this supply, as a factor in the life and growth of the city, can hardly be over-estimated, and it is safe to say that it is with a growing appreciation of its value that the residents of Portland regard everything that pertains to it or affects it in any way; and hence they are fast coming to feel in a measure justified in felicitating themselves upon their good fortune in being permitted to dwell in a city possessing such an abundant supply of pure water.

It is now nearly twenty-five years since the question of municipal ownership began to be discussed, and surveys were made looking toward securing a water supply for the city from a mountain stream.

In 1886 a citizen's committee, numbering fifteen of the substantial business men, was empowered by the State Legislature to

purchase or construct and operate water-works for the supply of the city. In the following year the Water Committee purchased the plant of the old Portland Water Company, which had been supplying the city with water from the Willamette River by pumps installed at a point on the river bank about 6 miles above the city; these works they continued to operate until the Bull Run gravity system was completed in 1895. Mr. Clarke.

The surveys for the gravity system, made under the direction of the late Isaac W. Smith, M. Am. Soc. C. E., who also constructed the works, developed the fact that the most available and altogether satisfactory source of supply was to be found in the water-shed of Bull Run River, in the foothills of the Cascade Mountains, eastward from Portland. The point finally selected for the intake is situated on the Bull Run River, about 5 miles from its junction with the Sandy, a tributary of the Columbia, and 30 miles from Portland, the elevation of the intake being 720 ft. above low water in the Willamette River. This point is in the edge of the foothills but well above the general level of the valley, while thence eastward the ground rises rapidly to the summit of the Cascade Range.

The entire western slope of the range is covered with a dense forest, and the work of exploration is difficult at all times. Little was known regarding the water-shed of the Bull Run prior to the time of making the surveys for the city. From the maps on file in the office of the United States Surveyor-General, the approximate area of the water-shed was known to be about 140 sq. miles. The existence of a lake near the summit of the range was also known, and but little other information was available concerning the region east of the point selected for the intake to the conduit. It should be stated, however, that prior to the selection of this stream, as the source of supply for the city, the main stream and the lake were explored by engineers in the employ of the Committee, and it was thereby determined that the flow of the stream was ample to provide for the future needs of the city.

In 1891 additional explorations were made by Mr. Frank T. Dodge, Superintendent of the Water Department, and, as a result of his recommendations, the Water Committee made formal application to the Department of the Interior for the withdrawal of the entire region as a Government reserve. This withdrawal was accomplished on June 17th, 1892; under the name of the Bull Run Forest Reserve, covering an area of 222 sq. miles and entirely surrounding the water-shed of the main Bull Run River.

Regarding this reserve the following statement is made:

"The United States will not sell any land in this reserve, nor permit timber to be removed from it, nor allow sheep or cattle to

Mr. Clarke. be pastured thereon. So long as the laws governing these matters remain unchanged, the water supply of Portland cannot be injured, providing the law to prevent forest fires on the public domain is properly enforced. The forest shades the snow which every winter covers the land deeply, and retards its melting; the undergrowth protects the soil and prevents it from being washed into the streams. The result is that no settling reservoir is needed, the water is always clear as crystal and free from sediment even during the greatest freshets. It is so cool that it does not need ice to make it palatable."

At the time the Bull Run reserve was established there were within its borders but few tracts claimed by private parties, and these were mostly held as timber claims by non-resident owners. Only two or three of the claimants ever made any attempt to build houses or make any permanent improvements in the way of clearing and cultivating the land. In a very few years the Water Committee succeeded in acquiring control of all improved claims, and has since continued the work of extinguishing private title to all lands within the reserve. At the present time the entire reserve above the intake is absolutely uninhabited.

From the beginning it has been realized that the greatest danger which threatens the water supply is that due to forest fires, which are very destructive during the summer and early autumn of especially dry seasons, these fires being usually due to the carelessness of hunters, fishermen and campers within the reserve or along its borders. In order that the danger from this source may be reduced to a minimum, the reserve is patrolled by forest rangers employed by the Government, and, in addition, extra patrolmen are frequently employed and paid by the Water Department, in order that a thorough inspection and isolation of the district may be maintained. This work is in charge of the officials of the United States Forestry service. In furtherance of this protection work a special Act of Congress, passed April 28th, 1904, prohibits all unauthorized persons from entering the reserve, all trespassers being liable to a fine not exceeding $500.

The low-water flow of Bull Run River is estimated to be from 65 000 000 to 70 000 000 gal. per day. If a larger quantity should ever be required, it would be a question of storage in Bull Run Lake or elsewhere. Rainfall observations, at the head-works, at the western border of the reserve, show a yearly precipitation of about 70 in., while, at the higher or eastern portions of the reserve, it is undoubtedly much more. It will thus be seen that the average run-off from the rocky and precipitous Bull Run water-shed, of 140 sq. miles, must largely exceed any probable requirements. It is estimated that Bull Run Lake alone will afford ample storage for many years to come. By a comparatively short tunnel, the lake

could be drawn upon so as to supply an extra 100 000 000 gal. per day for the possible 60-day period when the stream is at its lowest stage. Mr. Clarke.

By special Act of the State Legislature, passed in 1906, the entire flow of Bull Run River is secured for the exclusive use of the City of Portland.

The following is an analysis of a sample of Bull Run water taken from the stream after a heavy rain:

Total Fixed Ingredients.

"2.7 parts in 100 000 parts by weight, or 1.89 grains per imperial gallon (of 10 pounds avoirdupois) consisting of:

	Parts in 100 000.	Grains per gallon.
"Silica	0.56	0.392
Oxides of iron and aluminum	0.08	0.056
Calcium carbonate	0.39	0.273
Magnesium carbonate	0.27	0.189
Chlorides, sulphates and Carbonates of alkali	0.40	0.280
Organic matter	1.00	0.700
Total	2.70	1.890

"The carbonates of lime and magnesia are in the form of soluble bicarbonates. The organic matter is mostly in the form of suspended vegetable substances and partly insoluble products of their decomposition. Microscopic examination of the sediment, and chemical tests of the water show the absence of deleterious organic matter. Only traces of ammonia were found, while nitrates and nitrites could not be detected, showing absence of nitrogenous organic matter. To sum up, the water ranks among the best on record for domestic use."

George A. Soper, M. Am. Soc. C. E. (by letter).—It is by no means clear what sort of discussion was desired by the framers of this question. Its wording suggests that, in order to have clean water, we must either build filtration plants or purchase the land through which the water flows. This, of course, is not true. Mr. Soper.

In the average case, people using impounded supplies need not feel that they are driven upon either horn of this dilemma—certainly not to the purchase of whole water-sheds. This is at once the most expensive, least scientific, and most impracticable way to proceed in order to protect a water supply against pollution. For example, it would cost New York City about $58 000 000 to buy the drainage area of its new water supply, provided it could be had at the average rate of $100 per acre; and mere ownership is by no means an insurance against pollution.

The question suggests that pollution may perhaps be tolerated if only filtration is used. This is utterly wrong. It is wrong in

Mr. Soper. principle and not justified in practice. Filtration is a cure, and an excellent cure, as cures go, but it is not an infallible safeguard. Deliberately to allow filth to pollute a water supply with the idea that the water will eventually be cleaned by filtration shows a beautiful trust in filters and a greater confidence in the men who run them; but it is not good sanitary engineering. It has been well said that what we need in water is not repentance but innocence, and when it is possible to keep water pure this should be done by all means.

The extent to which water supplies can be protected against pollution depends upon a number of circumstances, but chiefly upon the amount of attention which engineers and others interested in pure water are willing to give to the subject. If water-works people would give an amount of attention to regulating the drainage, inspecting the streams, and superintending the disposal of harmful matters on the water-shed commensurate with the time and money which they give to handling the water after they get it, nearly all danger from impounded supplies could be avoided.

Protection means a number of things which the public looks to engineers to understand, but which engineers frequently consider can be understood only by medical men; but physicians, as a rule, are not competent to handle sanitary matters. It is time that engineers accepted the responsibility, and undertook to deal with these subjects themselves.

The sanitary protection of a drainage area means, first, knowledge of the conditions where permanent and accidental defilement may take place; second, the careful design of measures to protect the water against these danger spots; third, adequate provision of law to carry out the measures; fourth, a settled intention to protect the water.

If the purpose exists, difficulties respecting the other requirements will disappear. Experience shows that filth can be kept out of water, if only there is a determination to keep it out.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

FOUNDATIONS.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"(*a*) What is the best system of construction for foundations of heavy structures on ground such as that of the City of Mexico, which is an alluvial deposit about 300 ft. in depth, and similar in character to that at New Orleans?

"(*b*) Will iron or steel used in foundations, independently or in combination with other materials, last indefinitely when in direct or indirect contact with water?

"(*c*) Will the strength and durability of concrete in foundations be affected if before setting there is: (1) an excess of water; (2) lack of compression; (3) too rapid desiccation?"

BY MESSRS. JOHN F. O'ROURKE AND J. A. L. WADDELL.

JOHN F. O'ROURKE, M. AM. SOC. C. E.—In the three questions submitted in connection with "Foundations," the first calls for the design of systems of construction applicable to the foundation of heavy structural work in the City of Mexico, the ground being an alluvial deposit, about 300 ft. in depth, similar in character to that at New Orleans, and taking into account the supporting power of the more or less unreliable material upon which the structure must be carried; while the other questions relate to the durability or strength of the materials in the foundation structure itself, and the manner in which they are placed, without reference to the character of the material upon which the structure is carried. Mr. O'Rourke.

*Further discussion, had at the Convention, will be published subsequently, and additional written discussions are invited.

Mr. O'Rourke. In regard to the first question, assuming that the material is as stated, namely, alluvial deposit having no very great bearing ability, one can approach it from a more general point of view than the question itself suggests. Every railroad engineer has had more or less to do with the carrying of structures or embankments upon swamps and other soft ground, and the ways by which this has been accomplished successfully are so numerous, and oftentimes so simple and well known, that its solution, with regard to carrying heavy structures in the City of Mexico, involves but another form of a very old problem.

It must be borne in mind that soft ground possesses varying powers of resistance to pressure, dependent very largely upon the degree with which it is confined. There are two ways in which the best results are obtained. One is to place the foundations at such a depth below the surface that the surrounding superimposed weight of the material itself prevents the ground from rising; and the other is by the use of one or another form of column to transfer the weight, through the friction on its sides, to the underlying material; enough surface to be brought into such contact to distribute the weight and reduce the stress to that which the material can bear without further movement.

It is not necessary to go into lengthy discussion of either system, since both are well known. The writer has built culverts, and even heavy bridge piers and abutments, upon material into which a man would sink if he attempted to stand upon it, by simply distributing the weight over an area which acted as a whole, because the structure was sufficiently strong to act as a unit in applying the pressure. No formula or rule seems to be applicable by which this area can be fixed, nor can the united resistance which soft ground offers under such conditions be always accounted for, but it is known by experience that material little different from mud will sustain pressure up to 1 ton per sq. ft. after the initial settlement has taken place, when the area involved is considerable and the loading has been uniformly applied over the whole surface. The same is true of the column system, of which the most familiar example is the ordinary wooden pile. It is a common experience, in building trestles across swamps and marshes, to find that a pile which can hardly sustain its own weight when driving has ceased, will, in a few days, take such a "set" that several heavy blows of the pile-driver hammer are necessary to start it again, and when started it will drive about as easily as before, until the harder material is reached; the fact being, however, that given a reasonable penetration in the soft material, the subsequent stability of the pile is not increased very much by its support upon solid bottom. The writer calls to mind, in particular, the case of the foundation

piles in the falsework of the Poughkeepsie Bridge, where piles were driven 100 ft. below the surface of the water into 60 ft. of silt, and were loaded with from 10 to 20 tons each during the erection of the fixed span, and in which no settlement was noticed during the erection of that span. When the first fixed span was completed, the falsework was taken down, and the piles were pulled out and used again in the erection of the second fixed span, the interesting fact developing that a dozen heavy blows of a 6 000-lb. hammer were necessary before a pile could be started, after which it drove easily and was then readily pulled out. Mr. O'Rourke.

It is clear that either of these methods may be used in providing heavy foundations in the City of Mexico, provided nothing in the ground itself would cause the decay of the material used. It is the writer's experience that wood, driven or placed in clay, is as completely preserved as though immersed in water, and, time and again in the construction of foundations in the lower part of New York City, he has removed timber—mud sills and stringers—which had been placed above the water level, but in clay, more than 100 years before, and has always found them in good preservation, where such conditions existed.

As the question of materials enters largely into the choice of the system to be used, if suitable wooden piles are not available, concrete or steel could be used, the choice resting on economic rather than engineering considerations. This is true of the "distributed pressure" system, also, using the three materials separately, or in combination, as may be found most economical or substantial for each case.

Iron and steel used in foundations, apart from conditions where electrolysis may occur, last indefinitely when in direct or indirect contact with water, provided the water remains unchanged. The reason for this is obvious. Water attacks iron or steel on account of the oxygen it contains, and, if this is a proportionately small quantity, the amount of oxygen contained in wet concrete or ground is negligible, and, having once been exhausted, the metal remains unharmed and protected.

The writer has seen many cases where immersion in standing water has been a matter of years, and in every case the effect upon the metal has been no greater than if it had stood for the same length of time in linseed oil. In one case bolts on the inside of cast-iron cylinders, filled with concrete, were exposed to the salt water in the Harlem River for more than 30 years, and when removed were found to be without rust. In another case a pipe was immersed for ten years in an Artesian well, the water in which had not been pumped for 10 or 15 years, and no corrosion of this inside pipe had taken place, the scale was still as fresh as when the pipe

Mr. O'Rourke. was new, and the tool marks of the pipe-coupling apparatus were still perfectly fresh.

Similar results came under the writer's observation in reference to the condition of rods and nails found in wooden foundations where the surrounding material was impervious to air, and in one case which came under his observation, at the time of the removal of the old elevated railway columns in Greenwich Street, New York City, prior to making way for the new structure in 1878, the bottom part of these columns and the bolts in the masonry were found intact, the corrosion gradually increasing until near the surface, where the material was almost entirely destroyed by rust. This experience with both wood and iron, where the renewal of the oxygen in the surrounding water was prevented, has been uniformly that of finding the material perfectly preserved, so that, in the writer's practice, he does not hesitate to advise the use of either material under conditions where a fresh supply of oxygen is excluded. The casing of concrete, in his belief, is an absolute protection against any oxygen penetrating to the surrounding water, and the uniform practice in foundation work in New York City, where both materials are used in combination, is to pay no attention to water-proofing as a preservation, but depend on the concrete to preserve the iron, which it does in the manner stated. There are exceptions to this, of course, but, generally speaking, where the water-proofing is put underneath the steel, it is for reasons connected with the water-proofing itself, more than from any intention to protect the steel in that way. As a matter of fact, water in one form or another is always a possibility, but conditions can be insured which will prevent its being changed, which is the great desideratum.

In answering the third question, it is the writer's belief that concrete should always be made so wet that it will not permit of ramming, but that, after the concrete has been put in place, a certain amount of spading, or "packing back," in the case of the form, so as to give a smooth finish, is all that is necessary in order to produce the most compact and durable concrete. As to rapid desiccation, there is no doubt that if concrete is dried out, or has not had sufficient water to permit of the chemical action or "set" being a finished chemical action, the concrete will be poor, or even worthless. It is not likely to occur, however, under most conditions, even where fresh concrete is allowed to set in the sun, but it has come under the writer's observation many times, in placing concrete under compressed air, that the air which escapes through the concrete in passing out of the air-chamber of a caisson, is most likely to create veins through the concrete from which the water evaporates before the concrete has had an opportunity to set, leaving that part of the

concrete in a condition which is changed very little from that of the dry materials before the concrete was mixed. Mr. O'Rourke.

In specifications, the writer would advise the entire elimination of the requirement for ramming in beds, and that the concrete should have sufficient water to enable it to puddle itself, with such handling and manipulation as are always incidental to placing it, the only exception being arch work and form work, where ramming may be necessary in order to drive the concrete into places which otherwise it might not fill properly—the ramming in this case being for the purpose of filling the mould, not for compacting the material. As to conditions where the rapid desiccation might threaten it, this should be provided against wherever possible. There is no doubt that wherever this occurs the quality of the concrete is injured and sometimes destroyed.

The writer regrets very much that owing to important business he is prevented from attending the Convention and presenting his views in person, and begs the members kindly to accept the foregoing as the best he can do under the circumstances to open this very important discussion. He will be greatly pleased to submit a further discussion of this matter before the subject is closed, and answer, as well as he may, any questions that may be asked during the discussion.

J. A. L. Waddell, M. Am. Soc. C. E. (by letter).—Early in 1900, the writer made an investigation of the subject of "Foundations for Important Buildings in the City of Mexico," in the expectation that he would be retained to design the foundations for a large public building then under contemplation for that city. For this purpose he evolved a new type of substructure for buildings to meet the special conditions existing there. Being disappointed in his expectation, and not wishing to lose the credit for the conception of the design, he prepared a paper for the *Mexican Herald* and had it translated into Spanish for one of the other leading papers of Mexico City. Both the original and the translation were published in March, 1900. The paper caused some little discussion in the local press, but, as yet, no foundations of the type proposed have been built. Some of the Mexican engineers stated that they did not like the design, but could give no specific objection to it except its novelty. Mr. Waddell.

For three hundred years Mexican architects and engineers have been overloading the foundations of buildings in Mexico City, notwithstanding the fact that the number of stories is generally limited to two or three. The writer's idea was to disturb the soil as little as practicable, and to load it only to the extent of 1 000, or, perhaps, 1 200 lb. per sq. ft. For isolated buildings, he advised cantilevering the base out on all four sides, and for buildings in

Mr. Waddell. blocks, cantilevering in front and rear. His method of construction can best be explained by the following quotation from his paper in the *Mexican Herald:*

"Bad as is the soil of the City of Mexico (and it would be difficult to find anything much worse for foundations), there is no reason whatsoever for failure of any kind in buildings that are properly designed to meet the conditions of the soil and those due to earthquakes. This may seem to be a rather sweeping statement, but the writer does not hesitate to make it, and to back it with his professional reputation.

"In order, however, to obtain immunity from the aforesaid dangerous conditions, it will be necessary for Mexican architects to modify many of their old methods of building construction, and to not only adopt the latest ideas but also go a step farther and accept some new ones, evolved especially to meet the peculiar conditions existing in this city.

"As is well known, the City of Mexico is located on the bed of an ancient lake; and by digging down but little more than a metre, water level is reached. The characteristics of the soil vary somewhat in different parts of the city; but, in general, it may be stated that there are some two metres of a soft, sandy clay overlying a stratum of so-called tepetate, which is really little else than a more solid layer of the superimposed earth, and not true tepetate at all. This stratum is on the average less than a metre in thickness, and below it lies an extremely soft mud of indefinite depth.

"Such being the case, the following axiomatic conclusions may be drawn:

"1st. Piling is not applicable for consolidating the ground, because there is no firm bottom for the piles to reach, and because the soil beneath the hard stratum is of too fluid a nature to offer any material resistance by side friction.

"2d. The hard layer should under no conditions be disturbed, and the total load that it sustains should be distributed over it as uniformly as possible.

"3d. The more of the existing soil that is left undisturbed over the hard layer, the more uniform will be the distribution of the load over the latter.

"4th. The less material used in the foundations of a building, the smaller will be the weight of the said foundations, and the greater will be the permissible load from superstructure that can be adopted.

"The general opinion in Mexico appears to be that a total superimposed load of one thousand (1 000) lbs. per square foot is about as high as can be considered safe for the soil of the city; but, if the writer had any important building to design, he would certainly first make a number of tests of the actual bearing capacity of the soil, and would be governed by the results thereof in proportioning the entire structure.

"As in any area of any magnitude, the soil overlying the hard stratum is much softer in some places than in others, it is impracticable to adopt the customary American method of so dis-

tributing concentrated, isolated loads as to insure a uniform settlement of the entire building; consequently, if this method be tried, it will certainly result in failure. Mr. Waddell.

"Again, the haphazard method of placing beneath the walls masses of concrete containing steel rails will not suffice; because such masses will not have the necessary strength and rigidity to prevent unequal settlement and the consequent cracking of the walls.

"With very soft soils of uncertain and unequal bearing power, there is but one method of preparing a foundation for a large, heavy building, that will ensure the structure against failure by cracking, and that is to support the superstructure upon a continuous platform of steel encased in enough concrete to preserve it effectively against oxidation, the said platform having sufficient strength and rigidity to bear without appreciable distortion all inequalities of loading from above, due to variations in amount and position of the live or moving loads, and to take care of the prejudicial effects of the unequal bearing capacity of the soil at different parts of the foundation. Or, in other words, the building should be floated on the soft soil by making it into a box with a rigid, continuous bottom.

"If the building be an isolated one in reference to other buildings, the platform can be extended beyond the walls so as to provide a much greater bearing area, and thus permit the adoption of an increased number of stories; but, if the said building be one of a block of houses, the base can be cantilevered out only into the street or alley (if there be one); consequently the number of stories will then be limited by the allowable maximum pressure on the soil.

"This is the type of foundation evolved by the writer specially for large and heavy buildings in the City of Mexico. It will certainly (if properly detailed) prevent all injury to the buildings from unequal loading and unequal supporting capacity of soil, and will aid materially, if not perfectly, masonry walls to resist earthquake shocks. However, to ensure the walls against damage by the latter, the framework of the building should be of steel construction; but of this, more anon.

"The details of the writer's proposed type of foundation are as follows:

"1st. If the surface of the ground be very soft or irregular excavate to an average depth of a couple of feet the entire area to be occupied by the platform, then roll with heavy rollers the bottom of the pit thus formed until the bed is firm, filling in with a mixture of clay and gravel any inequalities caused by the rollers traversing earth of varying softness, and keeping the rolled material slightly damp by sprinkling it with water from a cart.

"Next put in a thin layer of clay and gravel, dampen it, and roll it until it is compacted thoroughly, then another similar layer and another until the surface of the base is brought up to or a little above the average original level of the ground.

"2d. Lay out the steel work of the base so that the main girders come under the lines of the walls and columns, making them all of

Mr. Waddell. the same depth so that, by placing splice plates above and below at the intersections, all girders will be continuous from end to end.

"The proportioning and detailing of these girders constitute an engineering problem of no mean order, as it is these girders alone that must take care of all inequalities of both loading and bearing resistance, unless steel superstructure be adopted, in which case sway diagonals embedded in the walls will aid materially in resisting the bending caused by these inequalities, and will thus permit of a reduction in the amount of metal required in the base.

"3d. Next, run primary girders at convenient distances apart, parallel to one set of the main girders and riveting into the other set. These girders will carry no load except the local upward pressure from the soil pertaining to the small areas that they dominate.

"In section these primary girders can be either rolled I-beams or small built girders.

"Next, run small secondary girders into and at right angles to the primary girders, thus dividing the total area into small rectangles that are approximately squares. These secondary girders should be small rolled I-beams.

"Finally, run tertiary girders of still smaller I-beams into and at right angles to the secondary girders.

"The upper surfaces of the main, primary, secondary and tertiary girders should be approximately at the same level.

"It is almost unnecessary to state that, between the ends of the main girders which are cantilevered beyond the exterior walls, there are to be primary, secondary, and tertiary girders like those in the space bounded by the said exterior walls.

"4th. If there are to be steel columns in the superstructure, these should be located directly above the intersections of the main girders of the base, and should be so designed as to rivet into the latter and be braced thereto substantially by steel brackets or knees, which will lie within the walls.

"5th. The main and primary girders are to be sunk into the earth by excavating trenches therein, but the secondary and tertiary girders are to lie above the surface of the ground.

"There is to be a single layer of concrete covering the whole area and enclosing all the secondary and tertiary girders; and the portions of the primary and main girders which project below this are to be encased in the concrete with which the trenches in the earth are filled.

"By this design the weight of concrete in the base is reduced to a minimum, thus leaving the greatest possible portion of the permissible earth load for sustaining the weight of the superstructure and its live load.

"6th. This design reduces the functions of the concrete to merely two, viz., to act as a protecting covering for the steel, and to carry the upward pressure of the earth to the secondary and tertiary girders.

"7th. The detailing of the metal-work in the base, the location of girders and the splices in same, and the *modus operandi* of erecting the metal and placing it in the concrete are engineering details

of a purely technical character, so that it would be out of place to treat of them in a general paper like this, written, as it is, as much for the public as for the architects and engineers of the City of Mexico." Mr. Waddell.

The writer recognizes the fact that girders of reinforced concrete might be used to replace the steel girders in his foundation design, but, for the same strength and rigidity, their weight would be much greater, and, consequently, their use would not be so advantageous for meeting the extreme conditions of weakness inherent in the soil of the City of Mexico. It is possible that the tertiary, and perhaps also the secondary, girders, might be replaced advantageously by reinforced concrete, but, in the writer's opinion, this is doubtful.

In any case, the thickness of the made ground should be a little greater than the vertical distance from the top of the concrete platform to the bottom of the concrete in the trenches excavated for the main girders. The raising of the platform 2 or 3 ft. above the surface of the surrounding soil would be beneficial in more ways than one, because it would provide for a possible settlement of the foundation as a whole, and would prevent water, during rainstorms, from flooding the ground floor.

The *modus operandi* of constructing the foundations is as follows:

After the made ground is finished and the entire metalwork for the foundation is delivered, the trenches for the main and primary girders should be dug to the required depths, provision being made for 6 in. of concrete below the main girders. Then the entire metalwork should be assembled and riveted in true position horizontally, but at an elevation somewhat above its final position. A large force of men for mixing and placing the concrete should be provided in order that the concrete work over the entire area may be carried on simultaneously, thus avoiding dry surfaces in the mass, and insuring that the latter shall be truly monolithic. In concreting, the first step is to place 8 or 9 in. of soft concrete in the bottoms of the trenches in the shortest possible time, then lower quickly the entire platform to its final elevation, and fill the remainder of the trenches with concrete to the level of the made ground. Then cover the latter throughout with well-rammed concrete up to 2 in. above the top of the highest metalwork. By having a large force of men, the whole of the concrete work could be completed before setting takes place. Of course, the upper surface of the platform should be dressed off smooth with mortar before the concrete has dried.

In order to reduce the load on the foundations to the very lowest possible limit, it might prove advisable to adopt nickel-steel

Mr. Waddell for the main girders, and, in certain extreme cases, also for the primary girders. As all loads on the girders are practically static, it would be permissible to strain the metal to one-half of its elastic limit. The writer recognizes that the adoption of such a high intensity of working stress would involve cracks in the encasing concrete, but, in his opinion, these cracks would be so small as not to permit of moisture reaching the metal. Moreover, the raising of the basement platform 2 or 3 ft. above the level of the surrounding soil would prevent water from remaining for any length of time as high as the elevation of the lowest part of the metalwork.

It is to be hoped that the action of this Society, in discussing at its meeting in the City of Mexico the question of foundations for heavy buildings in that city, will induce Mexican engineers and architects to give the subject due and thorough consideration, and thus effect a radical change in foundation designing which has been sadly needed in Mexico City during the last three centuries.

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PAVEMENTS.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"Will the paving materials of the present be used in the construction of the pavements of the future?"

BY MESSRS. GEORGE W. TILLSON, J. H. HAYLOW AND CLIFFORD RICHARDSON.

GEORGE W. TILLSON, M. AM. SOC. C. E.—When one remembers that thirty years ago there was not a mile of the standard pavements of to-day in existence in America, is it strange that the thinking engineer wonders what new developments in street pavements will take place during the next thirty years? Will the principal changes be in the materials used, in the methods of using them, or both? Mr. Tillson.

In order to speak with any intelligence of the future of any industry, it is always necessary to become conversant with its past history as well as the present conditions.

At the risk, therefore, of repeating some things which the speaker has said in other discussions of the pavement question, he will review briefly some of the conditions and experiences which have led up to the adoption of the pavements now in use.

Paris and London did not have street pavements until they had become cities of 200 000 and 100 000 inhabitants, respectively. This might seem strange unless it were understood that wheeled vehicles did not come into general use until the sixteenth century, the

*Further discussion, had at the Convention, will be published subsequently, and additional written discussions are invited.

Mr. Tillson. transportation of merchandise in the interior being carried on by pack-horses and other beasts of burden.

The first pavements were built of cobble stones and of irregularly shaped stones. These latter were gradually improved in shape until finally they developed into the large, flat stones now in quite general use in Italian cities. They did not, however, resist heavy traffic successfully. Pavements of the above character have been disclosed in the excavations recently made in the streets of Pompeii. These must have been laid nearly two thousand years ago. Their construction, with large crossing stones at the intersections, plainly demonstrates that wheeled vehicles were used very little, if at all.

Pavements, however, improved slowly, and in 1826 a London engineer, after investigation on the Continent, reported that the best pavements he saw were those with specially prepared wheel tracks, 3 ft. in width, and 4 ft. apart, the space between being paved with small stones. He said, also, that these pavements would be too expensive for London.

As cities became more wealthy, and traffic increased, better streets were demanded, and the rough block was better made, until the Belgian block of Europe and the oblong granite block of the present were evolved.

This would seem to state briefly the development of the industrial pavement.

Pavements of the above materials, however, are not satisfactory for modern cities. Pavements, now, must not only be durable but noiseless and easily cleaned, in order to be at all satisfactory. A few years ago these might have been considered æsthetic qualities, but now they are necessary. Attempts to satisfy these demands have produced the asphalt and wood block pavements.

An important quality of a pavement is that it shall not be slippery, and the lack of this quality has prevented many a material from being used successfully.

Time will not permit the discussion of the different experiments that have been made with such materials as iron, hay, glass, etc., or why they failed; suffice it to say that the standard pavements of to-day are constructed of stone, brick, bitumen, and wood.

The perfect pavement has never been constructed. The speaker has no hesitation in stating that municipal engineers in charge of pavements have failed to solve satisfactorily the problem presented to them. In most constructive work, any result can be obtained if sufficient funds are available. An architect can build any kind of a residence desired; a bridge engineer can erect a bridge that will satisfy perfectly the requirements of traffic, and be pleasing to the eye; but a pavement engineer cannot lay a pavement that will be entirely satisfactory; and, in this statement, durability is not con-

sidered, but only the public requirements. A pavement is laid primarily to sustain traffic, but, no matter how well it does this, it is not a complete success unless it can be cleaned easily and is neither slippery nor noisy. What pavement will satisfy the above four requirements? But, to go further. Pavements are laid for the convenience of the public, and should an engineer be fortunate enough to construct a pavement that would fill these conditions, if it were of such a character that it would wear out quickly and require constant repairs, it would be a failure. Any interruption of the traffic of a street interferes seriously with business, and often causes material financial loss; so that it can be said that the perfect pavement must, not only have the properties named above, but must be so durable that its necessary repairs will not obstruct traffic seriously. Mr. Tillson.

The proposition then is, can the perfect pavement be constructed or approximated with the materials now prevailing, or must new materials be used? When it is known that the great improvements in pavements that have been made in the last thirty years have been mainly in the use of many new materials, the latter might be expected; but the speaker believes that the engineer himself is at fault, that he has not made the most of his opportunities, and that he has not made sufficient study of the needs and wants of each individual street. He appreciates fully, too, that, very many times, reasons other than engineering determine the character of the particular material. But he believes that too often an asphalt pavement is considered simply as an asphalt pavement, a wood pavement as only a wood pavement, without any serious consideration as to just how it should be laid to meet the requirements of any particular location. Specifications are too general. By a little study the cost of a pavement on one street may be reduced sufficiently to permit improvements to be made to a similar pavement on another and more exacting street, and the result may be two pavements which are relatively equal.

One great defect often found is in the foundations. It is generally accepted that in any work of construction the foundation is the important part. This is so well understood that it needs no elaboration. And yet, in pavement construction, it is constantly violated.

In order to get the greatest durability from a block pavement, the traffic should be applied directly to the tops of the blocks. And, in the proportion that this practice is varied from, to just such an extent is the life of the block reduced. If this needs confirmation, examine a trench which has been roughly repaved, and note the wear on the individual blocks.

It can be laid down then, as an inviolable rule, that, no matter

Mr. Tillson. what the character of the pavement may be, it must always be laid on a firm foundation.

It is now proper to discuss the different pavements in use, in order to learn, if possible, how they can be improved.

It is admitted by all that the first-class stone streets of Europe are better than streets of a similar class in America. The difference is principally in the blocks themselves. They are better dressed and more uniform in size. If more attention were given to the making of the granite blocks in America, the pavements would be less noisy and much more durable; and, as the noise is one of the greatest objections to stone pavements, anything that will reduce it is an important improvement. Granite as it is used becomes smooth and consequently slippery. This can be helped by making the blocks smaller; and, if they are well dressed, they can be set closely together, and so make it practicable to fill the joints with a bituminous paving composition alone, without gravel. This would also greatly reduce the noise. If automobile trucks come into general use, as they now bid fair to, the question of noise, now so important, will gradually grow less, and a pavement of well-dressed granite blocks, from 3 to 3½ in. thick, laid close together, with joints filled with some bituminous or similar mixture, will be very satisfactory for many streets.

One of the greatest objections to a good brick pavement is that it is noisy. It is often difficult, however, to tell by preliminary tests how satisfactory an unknown brick will be in a pavement, the product of different kilns often requiring different tests to enable the engineer to determine which is the best specimen. As brick is a material which is so available for many interior cities, and has given such excellent results, as far as durability is concerned, any practical change in methods which will reduce the noise will be of great benefit. As the speaker has had a limited experience with this material, he feels somewhat diffident about making suggestions, but thinks that, in addition to having the joints filled with a yielding substance, if the bricks themselves could be bedded in the same material, without too great an expense, the noise from the traffic would be materially deadened.

The construction of coal-tar pavements in Washington, some thirty or more years ago, and their development into the bituminous pavements of to-day, has made a greater change in street conditions than anything that has occurred since streets began to be improved. They filled several long-felt wants, as they were smooth, comparatively noiseless, and easily cleaned. Thousands of miles of such pavements have been laid since 1877, and their popularity is still increasing. The pavement mixture is artificial, and consequently is subject to considerable variation. There is no class

of pavements that taxes the ingenuity of the expert as much as the bituminous ones. When these pavements were introduced they were constructed according to the specifications of the contractor, who guaranteed them for a term of years. This practice has been kept up, to a certain extent. Few city officials hold their positions long enough, or have sufficient facilities for studying such subjects thoroughly enough, to decide arbitrarily on asphalt specifications. The general public looks askance at specifications prepared by contractors, but what can be done? The only thing is for the official to have sufficient knowledge to determine whether the conditions are drawn in the interest of the contractor or the city. Few engineers of the country are qualified to design asphalt pavements for different conditions. That is one reason why such pavements have so often failed. They were not properly designed for their work. The one great defect has been in the foundation, but the wearing surface is of great importance. An asphalt pavement is like a carpet laid upon a floor. Both the carpet and the floor must be good, or the result is bad; a failure in either causes a failure in both. Mr. Tillson.

The three forms of bituminous pavements now in use are sheet asphalt, asphalt block, and the bitulithic. Sheet asphalt pavements made the reputation of such pavements. The main objections to them are that they are slippery, and will not stand heavy traffic. Both these objections can be helped, if not overcome, by proper design. Clifford Richardson, Assoc. Am. Soc. C. E., in a paper recently read before the Society of Chemical Industry, advocated a pavement made up of a 6-in. concrete base upon which was to be laid 2 in. of a solid binder, covered with a 1½-in. wearing surface, this to take the place of the 1 in. of loose binder and 2 in. of wearing surface now in use. The speaker firmly believes that such a pavement would prove a success on many streets where the traffic now seems to be too heavy for asphalt. A proper selection of the materials for the wearing surface will undoubtedly reduce greatly the excessive slipperiness, although a hard, smooth surface must be slippery to a certain extent unless kept perfectly clean.

The asphalt block pavement is designed for steep grades. The aggregate of which the blocks are formed is coarser than in sheet asphalt, and this, together with the joints formed by the blocks, gives horses a better foothold. Good blocks will make a good pavement, and elaborate experiments are now being made, in order to determine a proper test for, and a proper method of testing, these blocks, so that their value can be determined before they are used.

The bitulithic pavement is expected to be smooth and not slippery. Its inventor started out to improve macadam, but finished by producing a new pavement. It has been used extensively and satisfactorily during the past 5 years, but the speaker's personal

Mr. Tillson. experience with it has been so slight that he will not attempt to discuss it.

Wood pavement has been used in 20-year cycles since the Forties, and has been steadily improved. At first, it consisted of blocks of any convenient wood laid carelessly on a sand base. The pine blocks of the Nicholson patent, laid on planks, followed in the Sixties. The blocks decayed and wore out unequally, and the pavement soon became in disrepute. Cedar and cypress blocks, made of fence posts, were used extensively in the Central West in the Eighties, and, in the present decade, has come the modern treated wooden block. This is a very different proposition from any of the others just described. They all failed from decay. The chemical treatment of the present blocks is expected to prevent this and make durability a question simply of wear. The modern wood pavement, when dry and first laid, is practically ideal. It is smooth, noiseless, and is easily cleaned. It is slippery, however, in moist or frosty weather. That is its greatest fault. If this objection can be overcome, it is bound to have a great future, especially if its preservative treatment is sure. It is expensive, however, and, as all lumber is increasing in value from year to year, it would seem to be difficult to reduce or maintain its cost as at present. This may possibly be done by obtaining different varieties of wood for use. It must be understood, however, that there is no material used in the constructive arts the value of which is so difficult to determine in advance as wood, and great care must be exercised in deciding to use a new variety. The kind which has been generally used is long-leaf, yellow pine, but this, while good, is expensive and is becoming more so from year to year. This wood comes from one section of the country, so that transportation expenses are high. The problem, then, is to discover, if possible, different kinds of wood, in different sections of the country, which can be used to advantage.

In summing up, then, the speaker would say that, in his judgment, the improvements in street pavements in the future are to be brought about by a different use of the materials now in vogue, rather than by the adoption of entirely new materials. That, by studying the needs of the different streets to be paved, by using present materials intelligently, both as to manner and combination, the municipal engineer can bring about results which, if not entirely satisfactory, will be a vast improvement over present practice.

Mr. Haylow. J. H. Haylow, Assoc. M. Am. Soc. C. E. (by letter).—The materials used in the pavements of the future, speaking of a future of from 25 to 50 years, will no doubt be principally the materials of the present. While the pavements of to-day fall far short of perfection, it is due to faulty construction and abuse, rather than to the materials used.

Of the many thousands of miles of pavements in the United States, only a small percentage has been constructed in a scientific and substantial manner. The construction of a scientific pavement consists, first, in the thorough and effective drainage of the subsoil; and second, in laying a substantial foundation, and unless this is done a full life cannot be obtained from any wearing surface. Mr. Haylow.

The greater part of the mileage of existing pavements is on streets occupied by street-railway tracks, and that portion next to the rails invariably fails first. This is sometimes caused by the faulty construction of the street-railway roadbed, or, by the track not being sufficiently rigid, and sometimes on account of the section of rail used. For instance, a tee-rail should never be used in a street paved with brick, granite block, or asphalt. With a tee-rail, the pavement has no protection whatever from the grind of the wheel flanges and steel tires, the groove in the rail being seldom, if ever, wide enough to be entirely free from the wider flanges and inequalities in the gauge of trucks, and the pavement being subject to the constant wear of steel tires.

Some cities have eliminated the narrow steel tire by ordinance, and, in the writer's opinion, the time is not far distant when all steel tires will become obsolete, their place being taken by rubber or pneumatic tires.

When the steel tire is eliminated, and when city engineers and street-railway officials become convinced that the girder rail—similar to the Trilby type—is the most economical and satisfactory rail for paved streets, and when the portion occupied by tracks is paved with brick, granite block or other material which can be laid on a sand cushion and the joints filled with tar instead of cement grout, then that part adjoining the rail will have the same durability as the remainder of the pavement. Asphalt should never be laid next to the rail.

A first-class street-railway roadbed should possess a certain amount of elasticity, but when the paving joints are filled with cement grout they become ruptured and are no longer impervious to water. The demand at present is not for new, but for a proper, handling of the present, paving materials.

Clifford Richardson, Assoc. Am. Soc. C. E. (by letter).—This subject is of very great importance, and Mr. Tillson has brought out some points of great interest, many of which the writer has been insisting upon for years, basing his conclusions on twenty years' experience with various forms of pavements in more than one hundred cities in the United States, in England, and on the Continent of Europe. Mr. Richardson.

There is no question that the failure of most of our pavements is due to lack of foundation as much as to any other defect. This

Mr. Richardson. is particularly true in the City of New York, where, as far as the writer is aware, a single well-constructed pavement does not exist. In a few, where there is a hydraulic cement foundation, other defects, such as the use of an open binder course in asphalt pavements, result in lack of support to the wearing surface. It is very fortunate that Mr. Tillson, by assuming the office of Chief Engineer of the Bureau of Highways, in the Borough of Manhattan, will be able to inaugurate some much needed changes in the character of the pavements to be laid in the metropolis of the country, and will thus do away with a condition which is a disgrace to such a large city.

The writer does not see that there is any possibility of the immediate introduction of any new form of pavement, but that all improvements must be in the methods used in the construction of those forms now in vogue.

Our granite block pavements do not compare favorably with the best in England and on the Continent of Europe, and we could well imitate the form of construction practiced in the City of Liverpool. As Mr. Tillson says, our blocks, owing to the fact that the surfaces are not well dressed, are made much too large to bed satisfactorily. A granite block, when well dressed, should not be more than 3 in. square. The long blocks now in use make a surface which is far from acceptable.

A large proportion of our brick pavements, even when supported by proper foundations, shows serious defects, owing to the careless way in which the bricks are embedded in the sand or cushion coat between the foundation and the surface. When properly constructed, brick pavements are very suitable for streets of moderate traffic, although they do not possess the smoothness or the freedom from noise of asphalt and wood block.

As Mr. Tillson remarks, we are much in need of some satisfactory method of making accelerated tests, not only of brick, but of wood, asphalt block, and sheet-asphalt surfaces, under conditions approaching in some degree those which exist in actual service.

The writer cannot agree with Mr. Tillson that wood block pavements are to be, to any degree, the pavements of the future, except as luxuries, owing to the scarcity and increasing cost of lumber, the short life of this pavement, and the impossibility of maintaining it in a satisfactory form. It is almost impossible to replace an opening in a wood pavement so that it is not uneven under traffic and plainly visible. London and Paris have had the most extended experience with wood block pavements, and the Municipal Council of Paris is so dissatisfied that it is endeavoring in every way to limit the area paved with wood. In London, streets

which carry heavy travel have to be replaced within at least 7 or 8 years, even where 6-in. blocks are used. Mr. Richardson.

The custom of using large quantities of impregnating material, as practiced in the United States, does not appeal to British and French engineers. The material used for this purpose does not increase the essential resistance of the wood to wear, and it is only necessary to use a sufficient quantity to prevent rotting, at least on streets of heavy traffic.

Blocks having a depth of only 3½ in.—which have been used of late in some of our largest cities—can hardly prove to be satisfactory. After a period of only 3 years, in New York City, they are showing signs of serious deterioration. The experience derived from these pavements will be valuable but expensive.

For many years asphalt blocks have proved extremely satisfactory on residence streets. In Washington, D. C., the writer recently inspected an asphalt block pavement, laid in 1883, which is now in nearly as satisfactory condition as when originally put down; but attempts to use this form of pavement on streets carrying moderately heavy traffic, as in New York City, have resulted disastrously. A good example of this can be seen on Fourth Avenue, between Thirty-second and Thirty-fourth Streets, in New York, where the blocks began to go to pieces within 18 months, and have been largely replaced within 2 years.

There is, no doubt, opportunity for improvement in the character of the blocks by using a cementing material less susceptible to temperature changes than that which has been used. In order to make it possible to store the blocks at the plant, and to transport them to the street without losing their shape, it has been necessary to use a much harder cement than was satisfactory under traffic. Some of the native bitumens and fluxes now available have made it possible to prepare a cement which is sufficiently soft at winter temperatures to make a block which will not disintegrate under traffic at that season, and at the same time be hard enough to permit of handling and storing in our hottest summer temperatures in the sun.

Within the last few years very decided improvements have been made in the form of construction of sheet-asphalt pavements, although these improvements, owing to the inertia of municipal authorities, have not been generally adopted. The best form of construction for a sheet-asphalt surface has recently been described by the writer, in a paper read before the New York Section of the Society of Chemical Industry, and details in regard to this need not be gone into here.

Bituminous concrete pavement is one of the forms recently developed to a considerable extent. When the cementing material is

Mr. Richardson. a bitumen of suitable character, and not coal-tar, such pavements serve extremely well on streets of light traffic. One constructed by the writer in Muskegon, Mich., in 1902, has been entirely successful after 5 years of constant use. Pavements of this description will, no doubt, be used to a considerable extent in the future, but they must be constructed on practical and not on theoretical lines. Already the large stone used in the original pavements of this type has been abandoned for smaller sizes, not exceeding 1 in. in diameter; and the quantity of fine material has been increased to a marked degree.

This form of pavement is not satisfactory on streets of heavy traffic, owing to the fact that the coarse stone is torn out very readily by the impact of horses' shoes, with resulting disintegration of the surface.

It seems to the writer that Mr. Tillson has not paid sufficient attention to the fact that that form of pavement is most desirable, especially in American cities where so many openings are made in the streets, which, while desirable in other respects, can be maintained most perfectly and most economically. It is certainly most unfortunate that our municipal engineers have done nothing toward determining the lasting properties of the various forms of pavements, under traffic of various concentration, and also the cost of maintenance of each type. For this purpose, very complete counts of the traffic should be kept in every city, in order to determine the cost of various pavements annually per ton of material hauled over them.

The writer is convinced that much better pavements could be laid by contractors if municipalities were prepared to pay a somewhat increased price. There is no economy in laying a pavement because it is cheap, if a stronger form of construction at a higher price would eventually result in a smaller annual cost.

Another unfortunate state of affairs in American cities is that the average citizen believes that when a street is once paved it is finished for a generation, or for all time, and little or no attention is given to its maintenance. In one city which the writer has in mind, at a meeting of the Board of Public Works, it was stated by a city official, that an asphalt pavement was of no value, and that no more pavements of this kind were desired in that city because, after the expiration of a 10-year guaranty, nothing having been expended on maintenance for 5 years, the pavement went to pieces.

Finally, it may be remarked, what is needed in the United States is not new material for the construction of street surfaces, but a proper and improved form of construction of those which have been in use for the last 20 years, together with a study of

the actual cost per annum per ton of traffic carried per linear foot of street. Unfortunately, data of this description are almost entirely wanting at present. Mr. Richardson.

That there is a large field for improvement in the character of pavements is quite evident, and this improvement must lie with the municipal engineer, who will probably not make the desired move until the citizens demand that he shall do so. The best contractors are always in favor of doing the best work compatible with the price they receive for it.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

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PAPERS AND DISCUSSIONS.

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ELECTRIC RAILWAYS.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"(*a*) What are the factors which determine the maximum economical grade for electric railways?

"(*b*) In establishing direct lines with heavy grades, under what conditions will it be found practicable to use electric locomotives and gas-engine generating stations, rather than traction by steam locomotives?"

BY GEORGE GIBBS, M. AM. SOC. C. E.

Mr. Gibbs. GEORGE GIBBS, M. AM. SOC. C. E.—It is difficult to furnish material for discussion of a question having such scope as the first part of this topic, except in the shape of generalities, which are either obvious or of little use in the special case which the engineer may have in mind. The length of line, the character and density of traffic, the location and length of grades, all have important bearings upon the economies, constructing and operating, in any railway proposition. It is probable, therefore, that the proposer of the question had in mind a discussion of the factors peculiar to the method of traction, rather than those affecting the location of railway lines in general. These factors result from the method of application of the power to the trains, and from the interconnected character of the apparatus which makes up the motive-power system.

* Further discussion, had at the Convention, will be published subsequently, and additional written discussions are invited.

On a steam railway the power plants are the locomotives; an electric road has its power system jointly in the locomotives (or the motor cars), in the continuous power conductor along the line, and in the central power-house. In the steam railway, therefore, the first cost of power equipment is fixed by the number of locomotives, independently of the location, or the length of line, or other outside considerations; with the electric proposition, the first cost of the power system is affected, not only by the number of locomotives or motor cars, but also by the magnitude of the other items of power equipment, and these items depend largely upon the grades, their length, and possibly their position. For instance, we can readily imagine a line with grades located in such a way that, with a given train interval, all trains may be ascending simultaneously; in such a case, the line equipment and power-houses must be designed to supply all trains taking power simultaneously, even if this maximum power is only needed for a small percentage of the total time. A location with the grades differently selected, even if the maximum gradient is not altered, might readily result in a much lower maximum demand at the power-house, and a consequent reduction in cost of the power system. Length and position, as well as rate of grades, therefore, are of much importance in an electric railway proposition. Mr. Gibbs.

The quantitative importance of these factors, of course, depends upon the character of the business; thus, where the traffic is very dense, requiring the operation of trains at short intervals, the relative location of grades is not as important as with infrequent train units, because, as the number of trains is increased, those ascending and descending the grades at any one time tend to balance, resulting in a relatively steady load on the power-house. The length of grade in an electric proposition has a peculiar importance because of the fact that electric motors have a rating in which the time limit comes in. Thus, for short maximum grades, the limit of motor capacity is in the commutation of the current; with long grades, the limit is in the heating of the motors, due to the cumulative effect of passing current through the motors, the resulting heat being not entirely dissipated by radiation.

As to maximum practicable gradients; this factor is generally a less limiting one in electric traction than in steam. For trains composed in whole or in part of motor cars, the question of adhesion may generally be dismissed, because the limiting grade, from the standpoint of safety, is generally less than that dictated by the adhesive limit. Even with locomotive trains, the problem is less serious in electric than in steam traction, because of the large proportion of the electric locomotive weight available for adhesion, and because of the facility with which trains may be double-headed

Mr. Gibbs. with electric locomotives; this arises from the fact that by multiple control two or more locomotives become in effect a single unit, and are not open to the objections of dual control, as in operating two or more steam locomotives on one train.

From the two factors, namely, the higher adhesion ratio and the selection of grade locations, it may result that, with an electric railway line, the economic grade may be greater than that possible with steam traction. For certain kinds of electric railways in a flat country, for instance the interurban trolley road, this facility for surmounting short but very heavy grades without reaching the adhesive limit is of great importance in separating steam and electric grades at crossings, without excessive cost, either for grading or for power plant.

The effect of gradient upon operating cost cannot well be discussed for the general case; in some cases the grades may have little or no effect, if they are short and the traffic is heavy; in other cases their length and location may have an important effect upon the quantity of fuel required and the economy of power-house operation. Of course, the cheaper the fuel, the less the importance of this factor in determining the line location.

Summing up, therefore, some important points to be considered in laying out an electric traction proposition are:

1.—The effect of density of traffic in averaging the load requirements at the power-house;

2.—The effect of location of grades, especially in infrequent service, in averaging load requirements at the power-house;

3.—The wider latitude in fixing the maximum grades because of the greater adhesion ratio;

4.—Limiting commutating effects on short grades;

5.—The motor heating effects on long grades;

6.—The less effect of grades on speeds because of the greater accelerating rate possible.

In order to use gas-engine stations successfully, for any electric traction project, it is necessary, of course, first, that gas engines and generators be obtainable of the proper characteristics for such work, and, second, that they will prove advantageous and economical. The form of the question appears to limit the subject to gas-engine prime movers for electric lines, rather than consideration of electric traction *versus* steam traction. In laying out the project in question, however, it is presumed that it would first be essential to determine whether electric traction of any kind would be advantageous, and then whether gas-engine would be better than steam or water-power prime movers.

A general discussion of electric *versus* steam traction, of course, opens up a vast subject, and to indicate even the treatment would

be beyond the limits of a brief opening discussion. Generally stated, for heavy grade work it may often be advantageous to adopt electric traction, not only because of economy of operation, but because of an increase in the capacity of the line consequent upon the use of exceptionally powerful electric locomotives which will enable the ruling loads to be taken over the grade without doubling; also because of the convenient application and control of electric locomotives, and because of the factors mentioned in connection with the discussion of the previous question. Mr. Gibbs.

Having determined that it will be economical or advantageous to use electric traction, it does not necessarily follow that gas engines would be the best means for producing power. Where water-power is available, and may be developed at moderate cost, on the line or within reasonable transmission distance of it, it will be found that such power will be more economical than either gas or steam. Where water-power is ruled out, and where the railroad is located within a short distance of coal mines, it may be that a steam-generating station would be more economical than a gas-engine station because of the lower first cost of the steam-generating plant.

In order that the gas-engine plant may be used economically, it is necessary that, as before stated, the machinery be available in units of proper size, that the details be worked out practically, and that they compare favorably with steam or water in first and operating costs. Doubtless these questions will be discussed in connection with the subject of gas engines, and, therefore, it may be stated here, that, from the point of view of economy of power, the gas-engine plant promises well, but from the view of availability, there appear to be at the present time two important limitations: the first is in the small over-load capacity of the gas engine, which is disadvantageous for fluctuating railroad loads, and the second is in the fact that gas engines and producer plants, up to this time, have been developed in relatively small units. Of course, it is true that some large gas engines have been built, but they can hardly be called a commercial article yet for general application to railway purposes.

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GAS ENGINES.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"(*a*) What is the best apparatus and most economical system for cleaning producer or furnace gas, to be used in gas engines?

"(*b*) To what extent is ordinary producer gas, made from bituminous coal, used in gas engines, and what practical results have been obtained by any methods for removing tar or soot?"

By Messrs. James Christie and Robert Heywood Fernald.

Mr. Christie. JAMES CHRISTIE, M. AM. SOC. C. E.—When furnace or producer gases are to be used in engines, it is necessary that the dust, or tarry matter, in the gas be removed entirely or nearly so. It is also necessary that sulphurous gas, if present to an objectionable excess, be reduced, or that the engine and its accessories be designed and constructed so that corrosion or electrolytic action will not ensue.

The necessity of clean gas in the engine is so important that scrubbers or washers, of the form and type heretofore used in connection with regenerators, etc., have not proved generally satisfactory, and, as a consequence, some trouble has developed in engines using gas insufficiently cleaned.

The gas must also be sufficiently cooled, and it is desirable that it should contain as little moisture as possible, as water vapor reduces its efficiency; and, as the various forms of washing apparatus

*Further discussion, had at the Convention, will be published subsequently, and additional written discussions are invited.

use a spray of water to remove the dust, the gas at the engine will be saturated, to a greater or less extent, depending on its temperature, unless special filters or vapor-absorbing devices are used. Mr. Christie.

Washing apparatus can be divided into four general types as follows: The baffle system; the coke scrubber; and two mechanical methods, one in which slowly revolving wetted surfaces are presented to the flowing volume of gas; the other a high-speed machine depending on centrifugal action. In blast-furnace practice, the usual dust catchers remain, as a preliminary, to reduce the work of the washer.

The first named types are so well known (or descriptions thereof are so readily accessible) that it is unnecessary to give their details here. The several mechanical washers are controlled by patent rights, therefore reference for description should be made to the manufacturers. It appears, however, that apparatus of the centrifugal type, especially when required to be of large capacity, as in blast-furnace practice, have proved highly efficient, and economical in space occupied and in water used. In recent American practice a removal of 97% of the solid impurities is reported.

The size and cost of the various apparatus depend on the amount of solids to be removed from the gas, and on the degree of purity required. Some manufacturers claim to remove the dust, so that not more than 0.01 gr. per cu. ft. of gas will remain. In a general sense, and for washers of considerable capacity, it may be assumed that the water consumption will vary from 10 to 25 gal. per 1 000 cu. ft. of gas washed; and the power required for mechanical treatment, from 0.10 to 0.20 h. p. per 1 000 cu. ft. of gas per hour, according to the amount of impurity present.

In producer practice, for power purposes, the fuel used has heretofore been confined to anthracite or other non-coking coal, and the coke scrubber is generally used for gas cleaning with the water spray for washing, and a supplementary coke chamber without water for drying the gas.

The abundance and cheapness of natural gas, throughout such a large area of the Middle States, has hitherto prevented any development of bituminous coal producers for power gas. The constant poking required to break up the coke, and the presence of either tar or soot or both, renders the production of gas with bituminous coking coal a more difficult problem than when non-coking fuel is used.

Recently, however, some promising work has been done with coking coal, and the experiments made at St. Louis under the direction of the United States Government have been instructive.

When bituminous coal is gasified in the producer under low pressure and slow combustion, say with a coal consumption of less

Mr. Christie. than 10 lb. per sq. ft. of fire bed, the quantity of tar suspended in the gas is comparatively large, the quantity of soot is small, and the temperature of the issuing gas is low. On the contrary, with more active combustion, when the consumption of coal is from 20 to 30 lb. per sq. ft. of fire bed, as in some mechanically-operated producers, the quantity of tar is small, or entirely disappears, the discharge of soot or lampblack is greater, and the temperature of the gas is much higher.

The quality of the gas appears to be about the same in each case. In addition to the soot carried over in the latter case, a considerable quantity of coke dust frequently appears; this comes from the fine particles of coal which fall through the atmosphere of high-temperature gas and are light enough to be wafted forward in the issuing stream of gas.

In modern producer practice, considerable quantities of steam are used advantageously—more than 1 lb. per lb. of coal consumed is common practice—with a result that the gas contains from 25 to 30% of its total volume of CO, or 10 to 15% of hydrogen. The steam also prevents the formation of hard clinker, and facilitates the discharge of the ash, the limit in its application being the amount that can be used without dampening combustion, or that can be decomposed in its passage through the incandescent fuel.

For the economical use of this gas in engines, it becomes necessary to provide apparatus which will cool the gas, utilize the extracted heat, remove or otherwise utilize the tar, remove and utilize the soot, and dry the gas after it has passed through a treatment with water.

For the economical use of this gas in engines, it becomes necesplished successfully by applying the heat to generate steam for the producer, or for preheating the air supply, or for both. Various methods of cleaning are proposed, but are still in the experimental stage. The tar problem has been handled in two ways: Separation by centrifugal action, as accomplished in the Government experimental plant at St. Louis;* and by the decomposition of the tar by passing the gas through a supplementary bed of incandescent anthracite or coke. The latter method is reported as being applied successfully in Germany to fuels of the lignite class, and has been applied to a limited extent in the United States, especially in the production of composite gas, which forms a specialty with manufacturers of power-gas apparatus.

This latter method of utilizing the tar has been accomplished by various methods, which differ in the details of application, and are claimed to be covered by patents. It appears, however, to be the most successful system for the complete disposal of tar, except

* Bulletins 48 and 261, U. S. Geological Survey.

by the use of auxiliary attachments to the mechanical cleaner, which require attention and renewal. Mr. Christie.

Obviously, the respective economies of the two methods depend somewhat on the demand for and value of tar in the vicinity. As the weight of the tar will be from 5 to 10% of the coal consumed, and sometimes much more when lignite is used in the producer, its salable value is an important factor in the problem.

When a large quantity of soot is formed, its removal has always been difficult, as it mixes with water very reluctantly in the scrubber, and is apt to create a nuisance, by the trouble involved in handling it, or by its obstruction of the gas passages. Sulphurous constituents in the gas have been dealt with by passing the gas through a mass of oxidized iron cuttings, a process which involves frequent renewal of the iron, if the content of sulphur is high. It is believed, however, that trouble from this source is not serious, if proper precautions are observed in the engine to avoid contact between materials which may promote corrosion or electrolytic action.

Altogether, it cannot be asserted that the generation of producer gas for power purposes, from bituminous coal, is yet in a satisfactory state of development. It will be understood that no reference is made here to the by-product recovery system, which is a distinct feature of producer practice.

Robert Heywood Fernald,* Esq. (by letter).—In presenting the following discussion, the writer's remarks are confined to the utilization of producer gas for power purposes in the United States. Mr. Fernald.

Rapid Development of the Gas Engine.—It was during the latter part of the nineteenth century that the gas engine found its way to the market, and, although many types have been produced in the past 20 or 30 years, it is only within the past 5 or 6 years that the development of large engines has been noted. This development started in Germany, Belgium, and England some 8 or 10 years ago, but marked progress has been limited to the past 6 years.

For many years the natural fuel of these internal combustion engines was city gas, but even this was too expensive except for engines of small capacity, and it was seldom found feasible to operate engines of more than 75 h. p. on this fuel. Cheap gas was essential for the development of the gas engine, but the early attempts in this direction were somewhat discouraging, and, for a time, the probability of encroaching to any extent upon the field occupied by the steam engine was very remote.

The theoretical possibilities of the internal combustion engine

* Professor of Mechanical Engineering, Washington University, St. Louis, Mo., and Engineer in Charge of Gas Producer Division of the Technologic Branch, United States Geological Survey.

Mr. Fernald. operated upon cheap fuel promised so much that the practical difficulties were rapidly overcome, with the result that steam boilers and engines in many plants were replaced by gas engines, and, at the present time, the internal combustion engine is rapidly becoming a serious rival of the steam engine in many of its applications.

The development of the gas engine in point of size has been exceedingly rapid. It was only 7 years ago that a 600-h. p. engine, exhibited at the Paris Exposition, was regarded as a wonder, but, four-cycle, twin-tandem, double-acting engines to-day run as high as 6 000 h. p.

Development of the Gas Producer.—This rapid advance of the large gas engine has been made possible by the great strides which have been made in the production of cheap gas directly from fuel through the aid of the gas producer. An early form of producer introduced in Europe, and one that is in very general use to-day, both abroad and in the United States, is known as the suction producer, named from the fact that the engine develops its charge of gas in the producer by its own suction stroke. Although this type of producer is used very extensively, its use is confined to small installations, usually not exceeding 150 h. p. As far as known, the first suction producer operated in the United States was installed in 1903, although other types of producers were tried in this country a few years earlier. A serious limitation to producers of this type has been the fact that, owing to the manner of generating the gas, no tarry fuels could be used, thus barring bituminous coals, lignites, peats, etc. The fuels in most common use for suction producers are charcoal, coke, and anthracite coal, although attempts are being made to construct suction plants so that they can be operated on the bituminous, or tarry, coals.

In order to meet the demand for the concentration of power in large units, instead of operating a large number of engines of small power capacity, the pressure producer came into existence. This producer develops its gas under a slight pressure, due to the introduction of an air and steam blast, and the gas is stored in a holder until such time as demanded by the engine. Owing to the fact that the gas may be stored in a tank before passing to the engine, and also because the gas is produced under pressure and does not depend on the suction of the engine for its generation, it is possible to introduce the necessary machinery for the removal of tar and other impurities from the gas, thus opening the way to the use of bituminous coals and lignites. Following closely upon the pressure plants came the down-draft producers, which fix the tar as a permanent gas and, therefore, can use the bituminous coals and lignites.

These pressure and down-draft plants have been in operation for

the past few years, but, in most cases, until very recently, the fuel has been anthracite coal, although occasionally plants ventured on the use of a few well-tried bituminous coals, known to be especially free from sulphur, and low in ash and in tar production. It remained for the United States Geological Survey, in its testing plant at St. Louis, to attempt the use of any and all bituminous coals, lignites, and peats, without reference to the amount of sulphur or tarry matter found in the fuel. It is gratifying to note that every coal received has been run through the producer, and that the results have been more than satisfactory. Mr. Fernald.

Number of Installations in the United States.—Within the past 2 or 3 years, the development in the gas-producer industry has been very rapid. At the present time there are probably twenty companies in the United States manufacturing gas producers for power purposes. At least twelve of these are fully established on a commercial basis and are in position to give proper guaranties when installing plants.

About one hundred and fifty gas-producer power plants, ranging in size from 20 to 6 000 h. p., are now in operation in the United States. One company alone reports twenty odd installations, averaging more than 2 000 h. p. each, and nearly as many more, averaging about the same size, contracted for or now being erected. The horse-power represented by these one hundred and fifty installations amounts to about 70 000.

The number of installations and the persistent development have already led the National Board of Fire Underwriters to issue special rules and requirements for the "Construction, Installation and Use of Coal Gas Producers (Pressure and Suction Systems)."

Of the total number of installations in the United States, it is interesting to note that about two-thirds are suction plants which operate on anthracite coal, charcoal being used in a few cases. Bituminous coal is used in approximately one-third of the installations, but this one-third of the number of plants probably covers in the neighborhood of from 65 to 75% of the aggregate horse-power rating, or in the neighborhood of 50 000 h. p.

Tests of the United States Geological Survey.—This gas-engine, gas-producer problem, with its possibility of driving out the steam engine in many large installations, has become so extremely important that the United States Government has made special provision for producer-gas tests at its coal-testing plant originally installed in connection with the Exposition at St. Louis. These tests have resulted in furnishing very valuable data on the relative consumption of coal per horse-power per hour when used by the steam plant and by the gas plant.

The steam plant upon which the tests were made consists of two

Mr. Fernald. 210-h.p. Heine boilers which furnished steam for a 250-h.p., simple, non-condensing Corliss engine. This engine was belted to a Bullock electric generator.

The producer-gas plant is a Taylor pressure-gas producer furnished by R. D. Wood and Company, of Philadelphia. This producer, designated as No. 7, is of 250 h. p. capacity. Together with the producer, are the usual economizer, scrubber, tar extractor, purifier, and holder.

The gas engine installed is a three-cylinder, vertical, Westinghouse gas engine, with cylinders 19 in. in diameter and having a 22-in. stroke, rated at 235 b. h. p. on producer gas.

The engine was belted to a 6-pole 175-kw. Westinghouse direct-current generator. The load on the generator was controlled by, and the energy developed was dissipated through, a water rheostat especially constructed for the purpose.

After installing this plant in 1904, one hundred and sixty-two producer-gas tests were made, prior to moving the plant to the Jamestown Exposition grounds, in March, 1907. The fuels used have been bituminous coals, lignites, and peats, from twenty-six different States, as indicated in Table 1.

TABLE 1.—Coals, Lignites, and Peats Tested by the United States Geological Survey at Its St. Louis Plant.

Bituminous Coals Tested:	Number from each State.		Miscellaneous Fuels Tested:	Number from each State.	
Alabama	3		*Brought forward*		138
Arkansas	2		Argentine	1	
Illinois	29		Brazil	1	
Indiana	15		California and Cinders	2	
Indian Territory	2		Florida Peat	1	
Iowa	1		Massachusetts Peat	1	
Kansas	2		Rhode Island Anthracite	1	
Kentucky	5		Virginia Pea Anthracite	1	
Missouri	1		Coke Breeze	1	
New Mexico	3		Miscellaneous Refuse	1	
Ohio	10		Coke	1	11
Pennsylvania	18		**Duplicate Tests of Coals:**		
Tennessee	3		Illinois	2	
Utah	1		Indiana	4	
Virginia	5		Kansas	1	
Washington	1		Ohio	1	
West Virginia	14		Pennsylvania	2	
Wyoming	5	120	Tennessee	1	
Lignites Tested:			West Virginia	1	12
Arkansas	1		**Duplicate Tests of Lignites:**		
California	1		North Dakota	1	1
Colorado	1				
Montana	3		Total tests made		162
North Dakota	4				
Texas	4				
Washington	3				
Wyoming	1	18			
Carried forward		138			

Mr. Fernald.

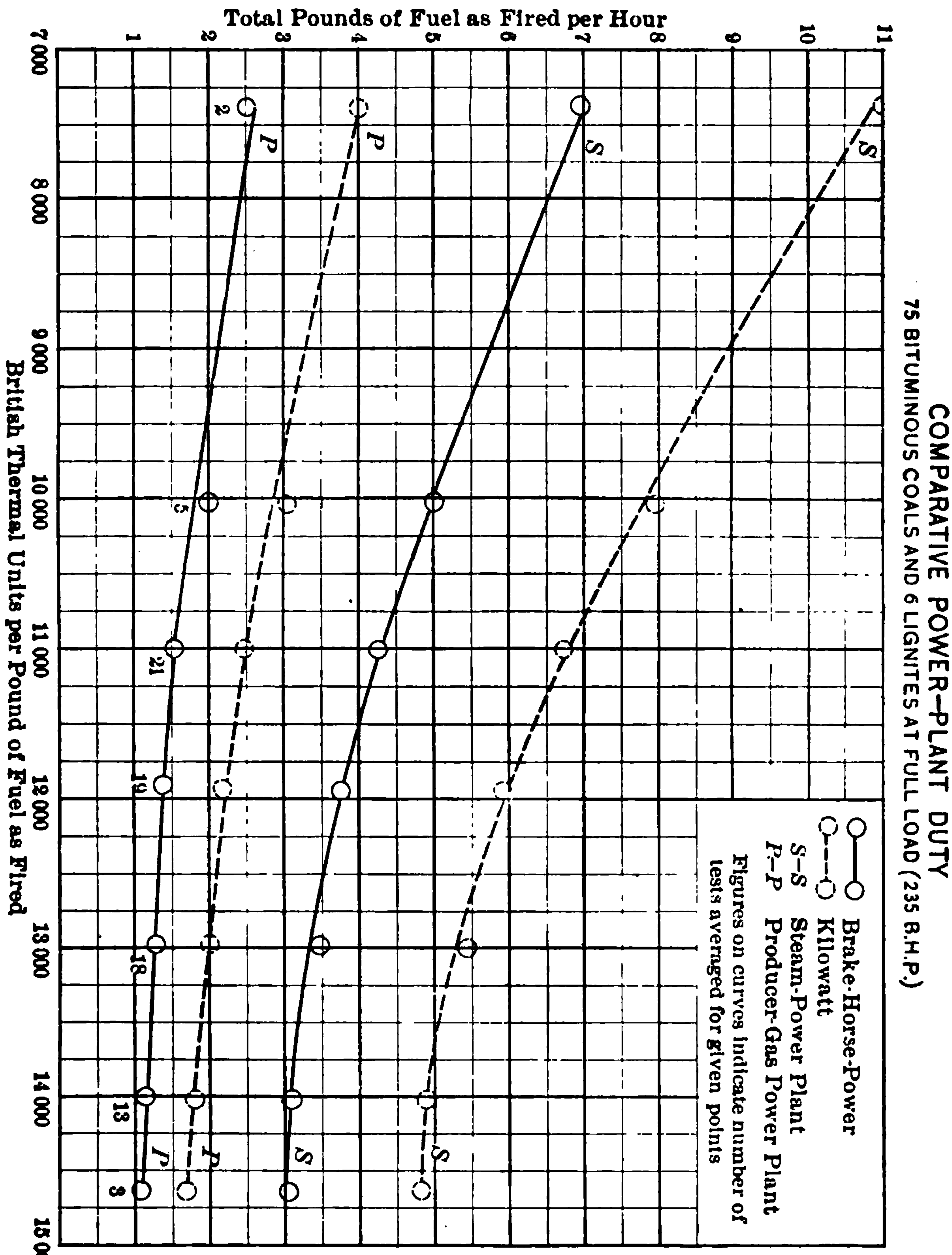

FIG. 1.

Mr. Fernald. *No Injurious Effects from Sulphur.*—Especial attention is called to the fact that, during all tests conducted at this plant, no attempt was made to remove the sulphur from the gas before it entered the engine. Considerable controversy has arisen in various parts of the country regarding the influence of sulphur upon the cylinders of a gas engine, leading, in some cases, to the introduction of this question into important lawsuits. The engine in use at the testing plant has received the full charge of sulphur contained in the gas, since the establishment of the plant, and shows absolutely no signs of injurious effects, although coals containing as much as 8.1% of sulphur have been used.

Relative Results of Steam and Producer-Gas Tests.—In considering the relation between the economic results of the two types of plants under discussion, namely, steam and producer gas, attention is called to the fact that, to-day, in the ordinary manufacturing plant operated by steam power, less than 5% of the total energy in the fuel consumed is available for useful work at the machine.

The curves in Figs. 1 and 2 show the great economy secured from seventy-five bituminous coals and six lignites when used in the gas producer instead of under the steam boiler. The results of the tests are officially reported on the basis of switch-board horse-power, but, in order that they may be of more practical value, they are given here on the basis of brake-horse-power and kilowatt—the efficiency of electric generator and belt in each plant being assumed as 85 per cent.

Especial attention should be called to the fact that several low-grade coals and lignites, which have proved of little value or even worthless under the steam boiler, have given excellent returns in the gas producer.

The ratios of the total fuel per brake-horse-power-hour required by the steam plant and the producer-gas plant under full-load conditions, not counting stand-by losses, are presented below as derived from 75 coals, 6 lignites, and 1 peat (Florida).

TABLE 2.—Ratios of Fuels as Fired per Brake-Horse-Power-Hour under Boiler to Fuel as Fired per Brake-Horse-Power-Hour in Producer.

	Coals.	Lignites.	Peat.
Average	2.7	2.7	2.3
Maximum	3.7	2.9	....
Minimum	1.8	2.2	....

In the case of the results for the producer-gas tests, the figures include not only the coal consumed in the gas generator, but also

Mr. Fernald.

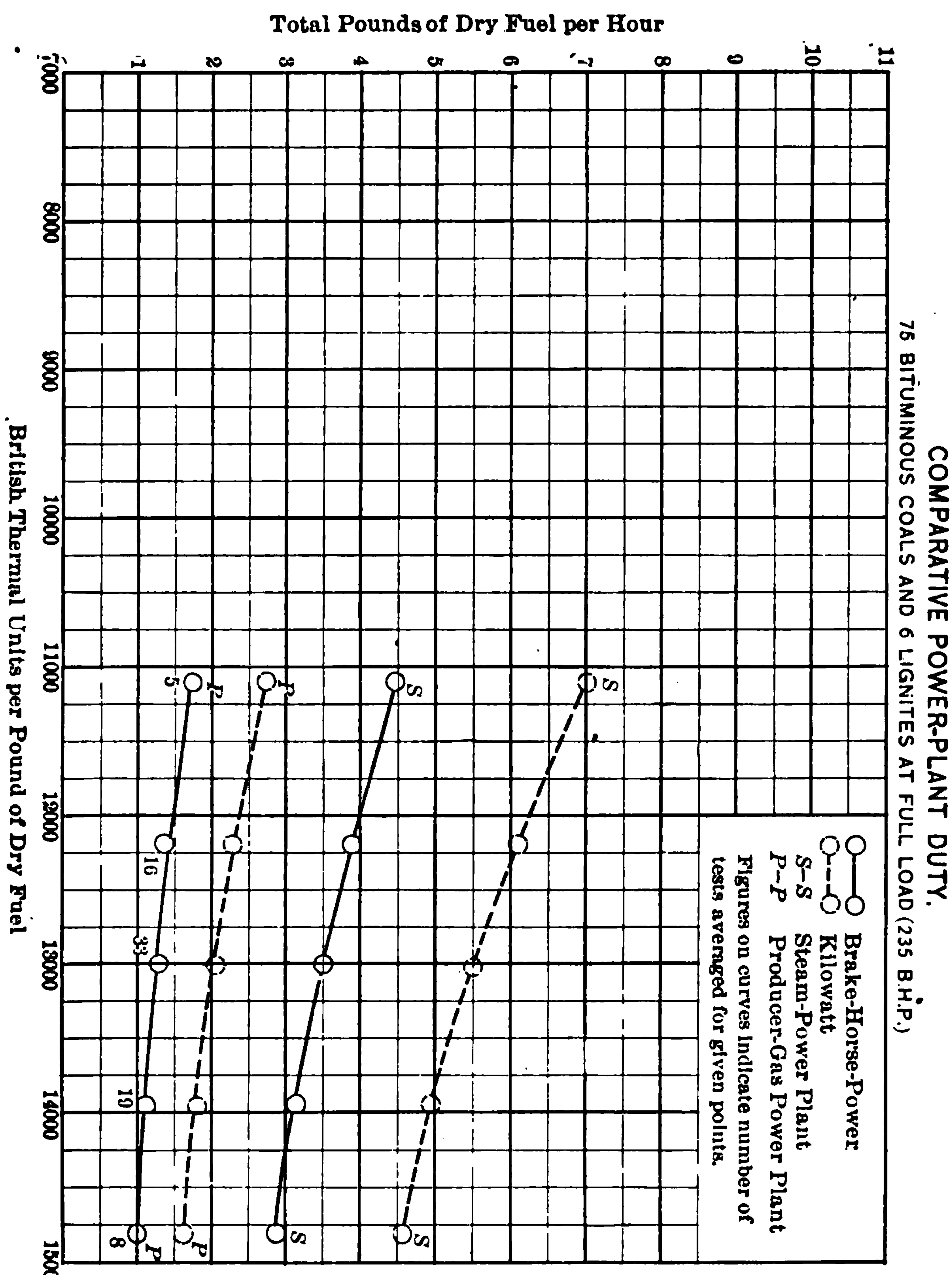

FIG. 2.

Mr. Fernald. the coal used in the auxiliary boiler for generating the steam necessary for the pressure blast, that is, the figures given include the total coal required by the gas-producer plant.

The relation between the coal required by the steam and producer-gas plant may be seen more clearly by an examination of Fig. 3, which presents graphically the results from thirty Illinois bituminous coals.

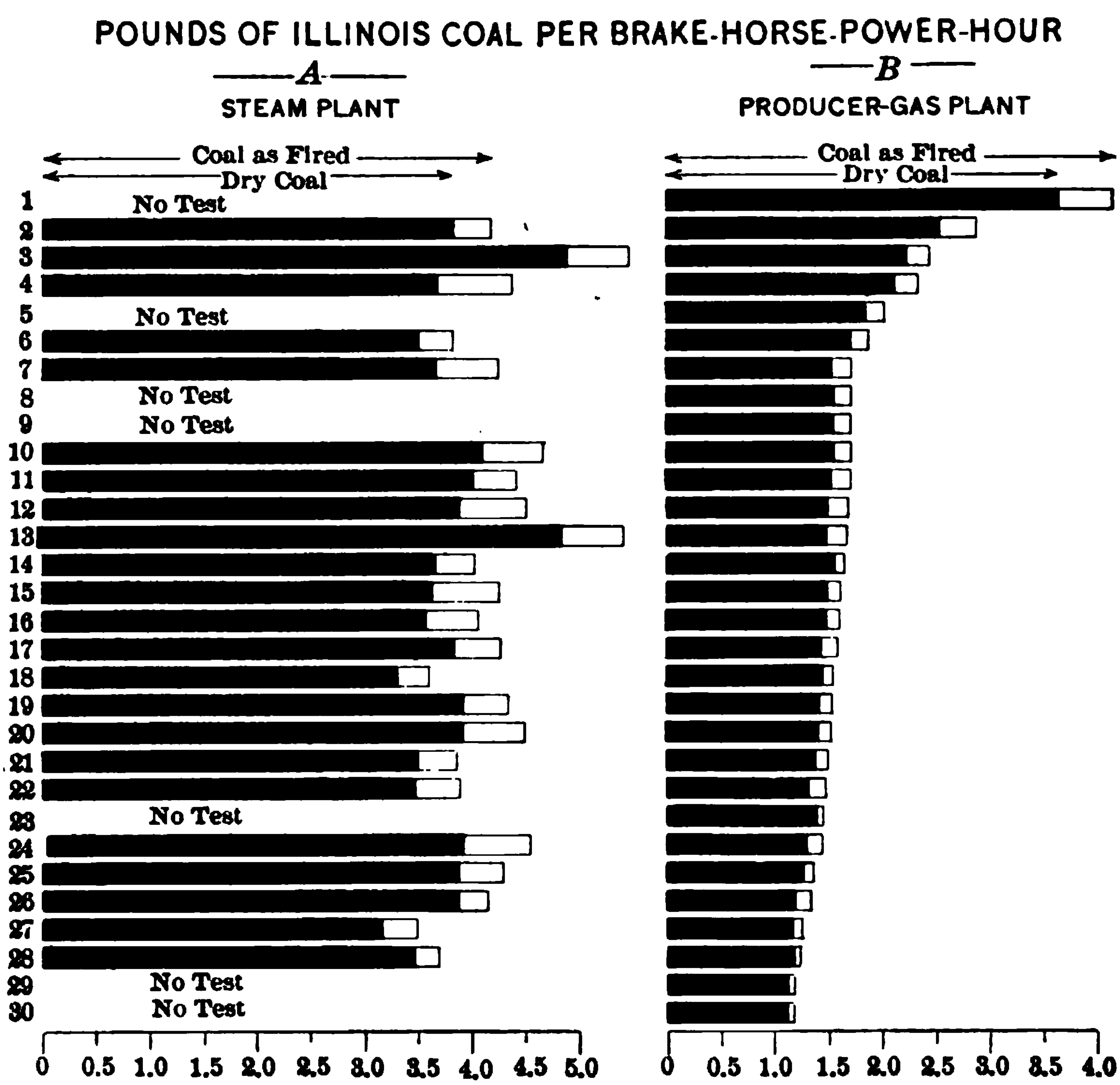

FIG. 3.

In considering the possible increase in efficiency of the boiler tests with a compound engine substituted for the simple engine used, the fact should not be overlooked that a corresponding increase in the efficiency of the producer-gas tests may be brought about under corresponding favorable conditions.

Too much emphasis cannot be given to the fact that all the tests upon bituminous coals, lignites, and peats were made in a

producer designed primarily for anthracite coal. It is, in fact, marvelous that any single plant can handle such a range of fuels. Not only is the producer passing through a transitional period, but the gas engine must still be regarded in the same light. In the larger sizes, the vertical, single-acting engine is being replaced by the horizontal double-acting type. Other changes and improvements are constantly being made which tend to do for the efficiency of the gas engine what compounding and tripling the expansions have already done for the steam engine. Mr. Fernald.

The engine used in the tests reported is, as already stated, of a type that is rapidly becoming obsolete for this size, namely, vertical, three-cylinder, single-acting.

A brief consideration of these points will lead at once to the conclusion that the producer-gas plant and steam plant used in these tests compare very favorably, and that any increase in efficiency in the boiler tests which might result from using a compound engine can be offset by the introduction of the more modern type of gas engine and a producer plant designed to handle the types of fuel used.

It should again be noted that many fuels are not fit to use under boilers. Many of these poor fuels have been used with the greatest ease in the gas producer, thus opening the way for the utilization of many fuels which have heretofore been regarded as practically of no value. Several of the poorest grades of bituminous coals have shown remarkable efficiency, and the lignites and peats have also responded with great readiness to the demands of the gas producer, thus opening the way to the introduction of cheap power into large districts which, thus far, have been commercially unimportant owing to the lack of industrial opportunities.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

JOHN EUGENE CHENEY, M. Am. Soc. C. E.*

DIED SEPTEMBER 25TH, 1906.

John Eugene Cheney was born in Lowell, Massachusetts, on February 12th, 1847. His parents were John S. Cheney and Cynthia Cram. His father was a direct descendant of Hannah Dustan. His parents lived originally in Ware, New Hampshire, from which town they moved to Lowell. In that city his father was Superintendent of the Merrimack Mills for many years, and afterward was engaged in manufacturing spools, bobbins, and shuttles.

In 1865 Mr. Cheney was graduated from the Lowell High School, and at once entered the Lawrence Scientific School of Harvard University. He was obliged to leave, however, after completing one year of the two-year course, but, in 1900, in recognition of the valuable professional work which he had done, the University conferred upon him the degree of S. B. as of the Class of 1867. This degree was prized more highly by Mr. Cheney than if it had been obtained in the usual way.

Mr. Cheney's first work, after leaving the Lawrence Scientific School, was at the Charlestown Navy Yard. He was also for a time with E. D. Leavitt, Jr., M. Am. Soc. C. E. He entered the employ of the Louisville Bridge and Iron Works, Louisville, Ky., in 1870, and remained there four years, obtaining valuable experience which served as the foundation of his future eminence as a structural engineer. He became an Assistant Engineer in the service of the City of Boston in 1874, and was appointed Assistant City Engineer in 1885. This position he held until his death, having acted frequently as City Engineer in the absence of the latter. During this period he had charge of the city bridges, and his work was of great value to the city, as he proved himself to be a very conscientious, capable and thorough structural engineer.

In Mr. Cheney's thirty-two years of service nearly all the city bridges were built or renewed under his supervision. The bridges which he built were of good design, substantial, and appropriate to their surroundings, and were constructed economically. There are in Boston many examples of the retractile drawn-bridge, a peculiar type of movable bridge having certain advantages for low-grade crossings. This type was developed by Mr. Cheney from a crude and

* Memoir prepared by the Secretary from information contained in an obituary notice for the Boston Society of Civil Engineers, by a committee composed of George F. Swain, E. D. Leavitt and Frederic H. Fay, Members, Am. Soc. C. E.

unscientific structure to one scientifically and economically designed, and remains as a distinctive feature of his work. He also perfected the wooden-leaf bascule bridge, and was among the first to build these bridges of iron. In connection with machinery for draw-bridges and various mechanical plants his work gained for him a deserved reputation as a mechanical engineer. He had an extensive experience with tide-water foundations built under the peculiar conditions found about Boston, and was recognized as an authority in such matters.

He designed and superintended the erection of a great many bridges, among them being the Charlestown Bridge, constructed under the direction of the Transit Commission, and containing the widest draw-span in existence. The new Cambridge Bridge, between Boston and Cambridge, its graceful arches making it the most beautiful bridge of its kind in America, was probably his greatest work.

In addition to his work for the City of Boston, Mr. Cheney's abilities as a structural engineer brought him many commissions from outside parties. For a number of years he was Consulting Bridge Engineer for the Concord Railroad, the Boston, Concord and Montreal Railroad, and their successor, the Concord and Montreal Railroad, and designed most of the metal bridges on that system, and also the train-shed at Concord, New Hampshire. He was also Consulting Engineer for the Connecticut River Railroad and the Massachusetts Central Railroad. He was consulted by many counties, cities, and towns throughout New England in regard to highway bridges. His advice was also sought by many architects in reference to foundations and steel-frame buildings. Among such structures in Boston may be mentioned the Exchange Building, the Exchange Club, the Tremont Building, the Tremont Temple, the New England Conservatory of Music, and the Central Building. The silverware factory at Concord, New Hampshire, built by the William B. Durgin Company, is a meritorious example of mill construction designed by him.

Mr. Cheney always studied his problems with great care, but was never afraid to adopt a novel or untried form of construction or a new idea after he had convinced himself that it was right. His designs were all ingenious, economical, well thought out, and well adapted to the conditions of each case. He was soon recognized as an able engineer, and as taking rank with the best structural engineers in America.

In 1875 he was married to Ellen M. Neal, daughter of the Hon. Peter M. Neal, of Lynn. After returning to Massachusetts, he lived in Lynn for ten years; he then moved to Boston, and at the time of his death and for some time previous, had been living in the suburb of Brighton. He died suddenly, of heart trouble, on September 25th,

1906. Mrs. Cheney, a son, and a granddaughter survive him. His son, Herbert Neal Cheney, also a graduate of the Lawrence Scientific School, is following his father's profession, being at present with the Boston Consolidated Gas Company.

Mr. Cheney was a member of the Massachusetts Society and Boston Chapter of the Sons of the American Revolution, and of the Society of Colonial Wars in Massachusetts. He was also a prominent member of the Boston Society of Civil Engineers. He was elected a Member of the American Society of Civil Engineers on May 7th, 1884.

While of a very modest and retiring disposition, Mr. Cheney was, nevertheless, a man of great force and determination. All who knew him loved and respected him, on account of his high professional acquirements and his lovable nature and sturdy integrity. He was always thoughtful of the rights of others, and was a man who would never do a mean thing. His brother members in the Boston Society of Civil Engineers have written of him:

"His memory will long be kept green in the hearts of those who knew him, and his death leaves a vacancy in his professional as well as his personal circle which will not soon be filled. Men like him, so strong, so modest, so capable, so thoughtful, so kind, so helpful, are rare indeed."

JOSEPHUS CONN GUILD, M. Am. Soc. C. E.*

DIED FEBRUARY 25TH, 1907.

Josephus Conn Guild was born in Nashville, Tennessee, on January 4th, 1862. His father was Major George B. Guild.

His primary education was received from the Mims School, at Nashville, from which he entered Vanderbilt University, receiving from that institution M. A. certificates in the Scientific Schools in the summer of 1883. Immediately thereafter he was appointed Assistant State Geologist. Resigning from this office a year later, Mr. Guild accepted an engagement as Superintendent and Engineer of the Refugio Gold and Silver Mining Company, Durango, Mexico.

After nearly a year spent in the tropics, to which he always had an aversion, he returned to the States, securing a re-appointment as Assistant State Geologist.

From 1885 to 1887 he held the position of Inspector of Mines, State of Tennessee, forming, at the same period, the partnership of Dickerson and Guild, Civil and Mining Engineers. The firm operated also a chemical laboratory, and, locating at Chattanooga, Ten-

* Memoir prepared by James Nisbet Hazlehurst, M. Am. Soc. C. E.

nessee, soon established a satisfactory practice, numbering as clients several of the larger iron and coal companies of the region.

Mr. Guild resigned the State office in 1887, and at about the same time formed a new professional association—with Mr. Linn White—for the practice of civil and mining engineering, and engineering chemistry, under the firm name of Guild and White.

During this period of great activity and industrial development in and about Chattanooga, the young engineers executed most creditably many important commissions for the furnaces, mines, railways and development companies of the district.

During 1889, an important professional engagement was the design and construction of the Cameron Hill (Chattanooga) Passenger Incline Railway. Of similar character, but of far greater magnitude and importance, was the commission to build the passenger incline up Lookout Mountain, executed in 1894, and uniquely interesting in many engineering particulars, being in fact one of the longest and steepest inclines in the world. Its length was 5 000 ft., with an ascent of 1 700 ft., and with gradients of from 10 to 68 per cent. One of the most difficult problems, successfully solved, was the proper arrangement of the cableways along the sharp vertical curve where the railway location encountered the palisade or rocky escarpment, before reaching the Mt. Lookout plateau. The line is now in daily operation, and is well patronized.

The necessity of undertaking the completion of an abandoned contract, upon which the firm had inadvisedly become bondsmen, turned the attention of Guild and White to the possibilities of municipal contract work, and thereafter, for a number of years, the firm name was a familiar one at contract lettings throughout the Southern States, and was synonymous with unvarying integrity and engineering skill of high order. Scores of water-works and systems of sewers were completed successfully by them, and the record was fully maintained and augmented, when, at the retirement of Mr. White, in 1896, the title of the firm was changed to Guild and Company, Incorporated, Mr. J. C. Guild being the first executive officer.

The corporation prospered greatly, growing in financial strength and engineering reputation, Mr. Guild's individual earnings being largely invested in the commercial, manufacturing and financial undertakings of his home city, Chattanooga. To his conservatism, energy, foresight, and shrewd business acumen, the firm prosperity and highly organized character of these institutions bear abundant witness, and stamp with the sterling mark this Captain of Industry.

The crowning achievement of his busy brain was his conception of the commercial possibilities which might accrue through the utilization of the great power of the Tennessee River.

Originally a project of the Army engineers for the improvement of the river's navigation, the potentialities of a hydro-electric instal-

lation in connection therewith were first recognized and made possible through Mr. Guild's knowledge of its engineering features, his strong personality, directed toward securing city, state, and national legislation, and his ability to obtain the necessary capital for this great undertaking.

At the time of his death Mr. Guild was largely interested in the financial outcome, and occupied the position of Chief Engineer to the Chattanooga and Tennessee River Power Company. This immense work is at the present time under construction.

Had he accomplished nothing beyond this undertaking he would have left to posterity a fitting monument to his memory. Originally intended by the Government as remedial work to facilitate slack-water navigation, it was proposed in 1900 to construct, some 30 miles below Chattanooga, a dam of heavy timber cribs filled with stone, the deck to slope downward each way from the crest. A lock of cut-stone masonry was also to be provided, the estimated cost being $1 000 000.

As a subsidiary proposition, Mr. Guild's conception was the practical utilization of the water-power at this dam and its conversion into electrical energy. In addition to the legislative and financial difficulties to be overcome, there were at least two most unusual engineering or physical problems to be solved. First, the distance or height between the upper and lower pools could hardly be less at times than 50 ft., and was destined to be one of the highest single-lift locks in the world. The second difficulty and exceptional hydraulic condition to be met was caused by the most unusual variation in volume of flow and the resulting head upon the turbine wheels. To secure uniformity of speed and regular output under such conditions, three wheels are specified to each vertical shaft, the two lower turbines being fixed for the lower volumes, while the third wheel is intended to utilize great volumes at the lower head.

The lock, dam and power-house are of cyclopean concrete in continuous work. To convey some idea of the installation, it may be mentioned that the three cableways in operation span 2 300 ft., with vertical slack of 100 ft., constituting in themselves remarkable equipment features.

Such, in these poor words, are the activities and achievements of a lifetime.

Of splendid physique, clean and wholesome morals, a fascinating personality, and with a brilliant, trained and highly analytical mind, Josephus Conn Guild was called from Life's labors to enter into rest. He died on February 25th, 1907, in his home in Chattanooga, Tennessee, at the age of forty-five, in the prime of vigorous manhood, and at the height of his brilliant achievements.

Mr. Guild was elected a Member of the American Society of Civil Engineers on June 1st, 1898.

DUNKIN WIRGMAN HEMMING, M. Am. Soc. C. E.*

Died March 22d, 1906.

Dunkin Wirgman Hemming was born in Drummondville, Quebec, Canada, on November 10th, 1860, of a distinguished English Canadian family—his father, Edward J. Hemming, being a Queen's Counsel, and the first man to take the degree of Doctor of Civil Law at McGill University. He was named for an uncle, the Honorable Justice Dunkin, and another uncle was Senior Wrangler in mathematics at Cambridge University, England.

Mr. Hemming was educated at Bishop's College University, Canada. After graduation he studied law and was admitted to the Montreal Bar with high honors; he became associated with a prominent firm of criminal lawyers of Montreal, but gave up a promising career to avoid disagreement with his father, who disapproved of his connection with the criminal branch of legal practice.

He then turned his attention to Engineering, and, by his own unaided efforts, worked his way up to an enviable position as an engineer, and at the time of his death was without a superior, if he had an equal, in his special work as Contractor's Engineer.

In 1886 he entered the service of The Canadian Pacific Railway as Rodman, and was Transitman when he left that road, in 1889. His next engagement of length was as Assistant Engineer, and later as Resident Engineer, in charge of construction of the Baltimore Belt Railway, including the Baltimore and Ohio tunnel and extensive open work; he left this work in 1893, and, after a short engagement as Locating Engineer for The New York, New England and Northern Railway he came to New York City where practically all his subsequent work was done, the greater part of it as Contractor's Engineer with some of the strongest contracting firms and on the most important construction work in this vicinity, including such work as the construction of the Columbus Avenue and Lexington Avenue cable lines; the laying of many miles of gas mains and sewers; a part of the Park Avenue Improvements of the New York Central and Hudson River Railroad; the laying of pneumatic tubes connecting the New York Post-Office with Sub-Stations; putting in condensed air plants; laying water mains and changing sewers along the Rapid Transit Subway; piers for the Manhattan Bridge, 145th Street Bridge; Riverside Drive Extension, etc. In 1904 he became Engineer for one of the Contractors for the Rapid Transit Subway and the Jerome Park Reservoir, and was engaged in this work at the time of his last sickness.

He was married on June 4th, 1896, to Florence, eldest daughter

* Memoir prepared by Albert Carr, M. Am. Soc. C. E.

of Augustus W. Kriete, a wealthy and prominent citizen of Baltimore, and granddaughter of Judge Hugh Lennox Bond, of the old Maryland family of that name.

After about ten years of exceptionally happy married life he was attacked by an unexpected illness, which took him away at the time of his greatest usefulness, and after he had reached a position to reap the reward of his earlier labors.

A Canadian by birth, he became a naturalized citizen of the United States and a staunch American in ideals and beliefs, thoroughly loyal to the country which had afforded him wider opportunities than his native land.

Of a very companionable nature, and with the happy faculty of remembering people, he had a very large acquaintance in business and in the various organizations with which he was connected.

He was a member of the Franklin Institute, the Canadian Society of New York, and St. George's Society of New York.

He was elected an Associate Member of the American Society of Civil Engineers on September 7th, 1892, and a Member on May 31st, 1904.

JACOB HAYS LINVILLE, M. Am. Soc. C. E.*

DIED AUGUST 4TH, 1906.

Jacob Hays Linville, of Pennsylvania Quaker ancestry, was born on September 23d, 1825, on the farm of his father, Arthur Linville, near the little village of Pequea, Lancaster County, Pennsylvania. His father, besides farming, was also engaged as a tanner and currier, at Gap, Pennsylvania. His mother, also a Pennsylvanian, was Elizabeth Haines.

His primary education was obtained in the local public schools, and was followed by a course in the Academy of Dr. Duffield at Belleview, Lancaster County, Pennsylvania, where he was prepared for his college entrance examination. He was matriculated at Union College, Schenectady, New York, in September, 1845, at the age of twenty, and was graduated, with the degree of B. A., in July, 1848.

Nothing has been learned to indicate that he had any predilection for engineering as his future profession; in fact, shortly after his graduation, he engaged in teaching, in his home public schools, for a short term only, and then he seems to have decided to adopt the Law as his profession, and, with that in view, in 1851 or 1852, he entered, as a student, the law office of William M. Meredith, Attorney at Law, in Philadelphia. Evidently, however, he dis-

* Memoir prepared by Walter Katte, M. Am. Soc. C. E.

covered very soon that the Law was not his vocation, for he terminated his studies in it in less than a year.

Then, apparently, he determined to adopt Engineering, and his first employment was as a topographical assistant in the corps of engineers making the surveys for the Lancaster, Lebanon and Pine Grove Railroad, in his home county. This was followed by an engagement as Assistant Engineer in the corps of the late William Hasell Wilson, Hon. M. Am. Soc. C. E., then engaged upon the location and construction of the Philadelphia, Media and Westchester Railroad. In 1857 he was appointed Assistant Resident Engineer, under Mr. Wilson as Resident Engineer, on the Middle Division (Harrisburg to Altoona) of the Pennsylvania Railroad.

On May 21st, 1857, Mr. Linville married Miss Celeste Virginia Rush, daughter of a Philadelphia merchant. Their union was blessed with only one child, a son, named Samuel Rush Linville, who in later life adopted as his profession that of "Electrician;" he died in Philadelphia on May 12th, 1899, in his forty-first year.

In 1863 Mr. Linville was appointed Engineer of Bridges and Buildings for the Pennsylvania Railroad, with residence and office in Altoona, Pennsylvania, the general headquarters and offices of that company's Operating and Construction Departments. This appointment seems to mark a singularly interesting and important turning point in Mr. Linville's professional career, and is apparently the initial one from which started his subsequent brilliant achievements in the specialties of design and construction of railroad bridges and buildings, remarkable for the reason that, as far as can be learned, he started with very little, if any, technical training or practice in those specialties. That he fully realized this, is disclosed by the following extract from a letter written by him to a close personal friend many years later:

"I went to Altoona with a young wife, with everything new to me. The bridges on the line were nearly all a wreck; I knew nothing of bridges, and had at my disposal nothing but Haupt's old book, all wrong. Orders came in to build new iron bridges, and I had to hustle, with many sleepless nights, and days spent over old patterns and new plans and calculations involving many changes and improvements in the plans of the original cast-iron chord, arch, and posts of the old Pratt type."

In 1863-64, the Pennsylvania Railroad Company having determined to prosecute the construction of the old Pittsburg and Steubenville Railroad, the question of bridging the Monongahela River at Pittsburg, and the Ohio River at Steubenville, at once became of very serious moment, as it was most energetically and violently objected to by the united coal and boating interests of those rivers. It was alleged, and not without a good deal of plausibility, that any

piers placed in their boating channels would inevitably and utterly destroy their business, by rendering it impossible, or so dangerous as practically to make it impossible, to continue the old-fashioned "broadhorn" system of floating their coal to market, on which, to a great extent, it depended. This controversy was stubbornly maintained on both sides, and was fought with most virulent animosity, through no end of "Courts" and "Legislatures," until, finally, a compromise was arrived at when the Railroad Company agreed to construct, over the navigable channels of the rivers, spans of not less than 300 ft. in clear between the piers, on the water line.

The river interests believed that the railroad company would find it impracticable to design and erect a span of that length to sustain safely the then prevailing weight of railroad trains, as, at that time, it was pretty generally believed, even by many technical experts, that 250 ft. was about the safe limit of spans of bridging to sustain the railroad "live loads" of that day. However, the President of the Pennsylvania Railroad Company at that time—Mr. John Edgar Thomson—was far too astute, and too good an engineer himself, to have ever agreed to such terms, had he not previously assured himself of perfect ability to comply with them. He had been for some years well acquainted with Mr. Linville, and entertained a high opinion of his abilities as a bridge designer, and had accepted his assurance that it was practicable to design metallic spans, from 300 to 350 ft. in length, with entire safety.

Mr. Linville made only one reservation, namely, that the railroad company should cause to be built for him a testing machine sufficiently powerful to "test to failure" full-sized bridge members. Mr. Linville had satisfied himself—as indeed had many other engineers of that day—that the old formulas and experiments of Hodgkinson, Fairbairn, Kircaldy, *et al.,* could not be relied on to give absolutely safe standards of the ultimate strength and moduli of elasticity of full-sized members, as they were derived from the results of laboratory tests made upon samples of very small sectional area and length, and were entirely lacking in proof that the ratios would hold good when applied to the areas and lengths of full-sized members. Mr. Thomson, fully appreciating the value of this "proviso," at once gave Mr. Linville *carte blanche* to have Messrs. William Sellers and Company, of Philadelphia, build such a testing machine as would fulfill all his requirements. Such a machine was built by that firm, and was set up in the railroad company's shops at Altoona, and, in all probability, was the first testing machine ever built of sufficient power to demonstrate the actual limits of ultimate strength and elasticity of full-sized metallic members of framed structures.

With this machine Mr. Linville conducted a series of tests from

which he derived reliable data from which to assign the necessary safe sectional areas for the members of "long-span" structures. This machine, having thus filled the requirements for which it was specially built, was subsequently bought by the Keystone Bridge Company, and re-erected in that company's Pittsburg shops. It is probably still in the service of the successors of that company, the American Bridge Company, now merged into the United States Steel Company. Thus did this Steubenville span of 320 ft. become indeed the "pioneer" of long-span bridging in the United States, which fact is attested to in the following quotation from the admirable paper* on "American Railroad Bridges," by Theodore Cooper, M. Am. Soc. C. E.:

"The era of long span truss bridges in America may be considered as dating from the building of the first bridge over the Ohio River at Steubenville, between 1863-64, by Mr. J. H. Linville. The channel span was 320 feet long and 28 feet deep. The top chord and posts were made of cast-iron. It was proportioned for a rolling load of 3 000 pounds per foot of track, a notable increase in the load heretofore in use."

In the latter part of 1864, Mr. Andrew Carnegie procured the incorporation, under the laws of Pennsylvania, of the Keystone Bridge Company, to take over the shops and business of the bridge building firm of Piper and Shiffler, of Pittsburg, at that time engaged principally in manufacturing and erecting the reconstructed bridges of the Pennsylvania Railroad upon the plans and specifications of Mr. Linville. This new company was organized with Mr. Linville as President and Consulting Engineer; John L. Piper, General Manager; Aaron G. Shiffler, Treasurer and General Superintendent, and Walter Katte, Secretary and Engineer of Shops and Erection.

Ample new capital being subscribed, the business scope and shop manufacturing facilities were at once largely augmented, resulting in this company speedily taking prominent rank among the leading bridge building organizations of the country. To this company the Pennsylvania Railroad Company awarded the contract for the manufacture and erection of the superstructures of the Steubenville and Monongahela Bridges, upon the plans and specifications previously prepared by Mr. Linville and accepted by the railroad company. The successful execution of this order, and the experience gained therefrom, so qualified this company and established its reputation as builders of long-span metallic bridges, that it at once entered the field as a very active competitor in the many bridging projects of the great western rivers, then being promulgated, all requiring exceptionally long spans. To this company were subsequently awarded the contracts for the manufacture and erection

* *Transactions*, Am. Soc. C. E., Vol. XXI, p. 1.

of the superstructures of the following notable long-span bridges, all of which were designed by Mr. Linville:

Monongahela River, Pennsylvania Railroad, at Pittsburg, Pa.;

Ohio River, Baltimore and Ohio Railroad, at Bellaire, Ohio;

Ohio River, Baltimore and Ohio Railroad, at Parkersburg, W. Va.;

Ohio River, Cincinnati and Newport Railroad, at Cincinnati, Ohio;

Ohio River, Cincinnati Southern Railroad, at Cincinnati, Ohio;

Missouri River, Draw Span, Hannibal and St. Joseph Railroad, at Kansas City, Mo.;

Mississippi River, Illinois Central Railroad, at Dubuque, Iowa;

Mississippi River, Keokuk and Hamilton Bridge Company, at Keokuk, Iowa;

Mississippi River, Draw Span, Chicago and Alton Railroad, at Louisiana, Mo.

The shop detailed working drawings of the great steel arch bridge over the Mississippi River at St. Louis, designed by the late James B. Eads, M. Am. Soc. C. E., and manufactured and erected by the Keystone Bridge Company, were also reviewed and revised personally by Mr. Linville in order to insure the successful erection of that great and novel structure, upon the cantilever suspension system, for which the Keystone Bridge Company was under contract responsibility.

During his service as Engineer of Bridges and Buildings of the Pennsylvania Railroad Company, Mr. Linville designed and supervised the erection of the new wrought-iron bridges over the Schuylkill River, at the Arsenal, Philadelphia, on the Delaware River extension of the Pennsylvania Railroad. This was the first bridge built with wrought-iron posts, and "upset" head-link tension members, and, by its use of hollow wrought-iron columns, started the long legal contest between the Phœnix Iron Company and the Keystone Bridge Company *et al.*, for alleged infringement of its patent rights. This was finally decided by Justice McKenna, in the United States District Court of Pittsburg, in favor of the defendant parties.

At about this time Mr. Linville resigned from the service of the Pennsylvania Railroad Company, and removed to Philadelphia where he opened an office for private practice as Consulting and Designing Civil Engineer. He was immediately commissioned by the Pennsylvania Railroad Company to prepare plans and specifications for the reconstruction in metal of many of its most important bridge structures, among which may be specially noted the following: "Dauphin Bridge," Susquehanna River, on the Northern Central Railroad; and the "Maryland's Creek" and "Ridley's

Creek" Bridges, on the Media and Westchester Railroad. He was also commissioned by the Lehigh and Delaware Railroad Company to prepare plans and specifications for the bridging of its line, including notable structures over the Delaware and Lehigh Rivers at Easton, Pennsylvania; and also by the Central Railroad Company of New Jersey for its long-span pivot draw-spans at Amboy and Newark, New Jersey.

In addition to his high attainments as a bridge designer, Mr. Linville developed marked skill as an architect, notably in the specialty of industrial buildings. Having a finely cultivated artistic taste, his designs for such buildings, while skillfully adapted to the technical requirements, were always architecturally attractive in their treatment. He was commissioned by the Pennsylvania Steel Company as its Chief Engineer during its constructive period, 1863-65, and designed and supervised the erection of all its shops and buildings at Steelton, Pennsylvania. For the Pennsylvania and the Philadelphia and Erie Railroad Companies he designed the shops at West Philadelphia, Harrisburg, Sunbury, Renovo, and Kane; also those at Uhrichsville for the Pittsburg, Cincinnati and St. Louis Railroad Company, and the new shops for William Sellers and Company, in Philadelphia.

In the early days of elevated railroad projecting Mr. Linville was consulted by Dr. Gilbert (one of the original promotors of elevated railway projects) to revise and perfect his plans, which resulted in his designing the structure which was subsequently manufactured and erected for the Metropolitan Elevated Railroad Company (afterward the Manhattan Elevated Railway Company) on its Sixth Avenue line, between Canal and Fifty-ninth Streets, New York City.

In 1876 Mr. Linville made a notable exhibit of engineering drawings and models at the Philadelphia Centennial Exposition, for which he was highly commended, and received a bronze medal.

About the year 1880 Mr. Linville and A. P. Boller, M. Am. Soc. C. E., were selected by the Pennsylvania Railroad Company to act as arbitrators in the settlement of a controversy between that company and the Long Branch Railroad Company. Subsequent to this Mr. Linville was induced to assume the Presidency of a railroad company which had failed in its efforts to complete a railroad in the southwesterly peninsula of Maryland. He took hold of this moribund enterprise, and by his untiring energy was successful in clearing off all its old debts and judgments; he called in and cancelled all its old stock and bond liabilities, issued new stock, and effected a contract with a Boston syndicate to complete the construction and equipment of the road. His efforts in this field, however, were finally frustrated by the failure of the financial promotors of the enterprise to support it.

In the latter days of his professional life, Mr. Linville was induced, by parties owning patents on an electro-magnetic printing telegraph device, to undertake to perfect their machine, as hitherto they had failed to make it work satisfactorily. He became most enthusiastically interested in it, and worked over it with such energy, that, in the end, his health was seriously affected, but finally he succeeded in perfecting the apparatus. It is claimed that his was the first machine, of this type of electrical telegraphic devices, that worked perfectly. In the end, however, it was a great loss and disappointment to him, owing to the failure of the promoting company to finance the enterprise adequately.

For many years prior to his death, Mr. Linville was a most acute sufferer from chronic catarrhal bronchitis and neuralgia of the head, which affected his eyes. Toward the end, his sufferings from these causes became so intense that he was compelled to give up his professional practice. Personally, his disposition was singularly loving and sympathetic, and all with whom he came in contact were greatly attached to him.

Mr. Linville was elected a Member of the American Society of Civil Engineers on March 3d, 1875.

GEORGE BENSON NICHOLSON, M. Am. Soc. C. E.*

DIED DECEMBER 2D, 1906.

George Benson Nicholson was born in Cheltenham, England, on September 24th, 1840. His father, John Nicholson, was an Irishman of English descent, and his mother, Matilda Jane Williams, was Irish by birth but Welsh and English by descent.

The family came to America in 1842, and after a short time located in Cincinnati, Ohio.

The father died in 1852, and the care and support of the family thereafter devolved upon George, the only son, and his sisters. Under these circumstances, there was not much time or opportunity for the boy to obtain a school education, and this was limited to the common schools, and one year in the high school of Cincinnati. But, all his life, he was a close student, and an extensive and discriminating reader, and thus largely made up the deficiencies in his early education. As illustrating this, it may be mentioned that he was familiar with the classics of his own tongue, mastered the French language, and was considered an authority upon heraldry —a specialty of which he was particularly fond.

* Memoir prepared by Samuel Whinery, M. Am. Soc. C. E.

He began the serious business of life at the age of sixteen, when he entered the office of the late A. W. Gilbert, at that time one of the leading engineers of Cincinnati, and thus commenced the special work and studies which were to lead to his professional career.

When the Civil War came on, young Nicholson was one of the earliest to volunteer as a soldier in the Union cause. He enlisted on April 22d, 1861, in Company K, Sixth Ohio Volunteer Infantry (widely known as the Guthrie Greys), and on June 18th he was enrolled in that regiment for three years, and served until the expiration of his term.

Of his career as a soldier, the following endorsement on his discharge papers affords a brief but eloquent record:

"HEADQUARTERS Co. K.,
"6TH REG., O. V. I.
"June 23rd, 1864.

"First Sergeant G. B. Nicholson deserves more than an ordinary notice of the meritorious service he performed during his term of enlistment. Although but a mere youth when he enlisted, he bore the fatigues of the arduous campaigns participated in by his regiment in West Virginia, Kentucky, Tennessee, Mississippi, Alabama and Georgia, with a degree of fortitude seldom found in one of his age and physique. He was ever a brave, intelligent, uncomplaining soldier, and behaved with more than ordinary gallantry in the engagements of Carrick's Ford (July, '61), Shiloh, Stone River, Chickamauga and Missionary Ridge. At the battle of Stone River he received a desperate wound, from which it was feared he would not recover; but his wonderful courage and determination carried him through. I deem this tribute the just due of one whom it was an honor to command, and whom I consider the beau-ideal of an American volunteer soldier.

"(Signed) J. M. DONOVAN,
"Capt. Co. K, 6th O. V. I."

His patriotic duty having thus been discharged, he again turned his attention to the profession he had chosen for his life work.

For a year he was engaged as Assistant Engineer in the military service of the Government, Department of Kentucky; then, for a short time, he was Mechanical Draftsman in the office of a patent attorney in Cincinnati. This was followed by 6 months' service as Assistant Engineer on street railroad construction in the same city. In March, 1866, he went to what was then the wilds of Montana and Idaho to locate and construct the Lewiston and Virginia City wagon roads, one of which he located through the Bitter Root Range of the Rocky Mountains; but, owing to inadequacy of funds, little construction work was done.

Returning to Cincinnati in March, 1867, he entered the service of the city as Engineer in Charge of Sewers, but in October of the

same year he gave up this work to re-enter the Government service as United States Assistant Engineer on the improvement of the Mississippi and the Missouri Rivers.

Early in 1869 he became Assistant Engineer of the Fifth Lighthouse District, and spent two years in charge of the construction and repair of light-houses, wharves, etc., along the coasts of Maryland, Virginia, and North Carolina.

From February, 1871, to February, 1872, he was Shop Inspector, for the Government, of the ironwork for the Rock Island Bridge. He then returned to the Light-house service, in the Eighth Light-house District (coast of the Gulf of Mexico), where he had charge of the design, construction, and repair of light-houses, keepers' dwellings, beacons, breakwaters, and other work incidental to the position, and the making of several hydrographic surveys.

On July 4th, 1873, he entered upon the work that was chiefly to occupy the remainder of his life—the location, construction, and engineering maintenance of the Cincinnati Southern Railway and its associated roads. At first he was engaged upon the surveys for the location of the Ohio River Bridge and its approaches at Cincinnati.

Then, in June, 1874, he became Division Engineer in direct charge of the construction of the first 40 miles south of Cincinnati, involving a large amount of difficult and expensive work. As the construction work on other divisions to the southward approached completion, Mr. Nicholson's jurisdiction was extended over them, and, for several years, after November, 1876, he had charge of the engineering work of the northern 160 miles of the road, under the late L. F. G. Bouscaren, M. Am. Soc. C. E., Chief Engineer.

The building of the Cincinnati Southern Railway was one of the notable public works of that period, and marked many substantial advances in railroad engineering. The Ohio River Bridge contained the longest truss-span attempted up to that time, and the Kentucky River Bridge was not only the highest railroad bridge in the world, but was the first cantilever bridge in America. The designs and specifications for the bridges for this road mark an epoch in the progress of bridge building. The road was a difficult and expensive project. The stretch from the Cumberland River to the Emory River, crossing the Cumberland Mountain, was probably the heaviest and most expensive one hundred consecutive miles of railroad ever built in America. There were twenty-one tunnels within the limits named. The construction work was begun under the late Thomas D. Lovett, M. Am. Soc. C. E., as Chief Engineer, with the late L. F. G. Bouscaren as first Assistant. When Mr. Lovett retired, Mr. Bouscaren succeeded him, concentrating upon the work his unflagging energy and his brilliant mind. The

work afforded a valuable school of experience for the younger men engaged upon it, several of whom, in addition to Mr. Nicholson, have since become well known in the profession.

In 1880 the lessees of the Cincinnati Southern Railway and the Alabama Great Southern Railroad, decided to build the New Orleans and North Eastern Railroad from Meridian, Mississippi, to New Orleans, Louisiana, and Mr. Nicholson, under Mr. Bouscaren, Chief Engineer, was placed in charge of the location and construction of the southern half, from New Orleans northward for about a hundred miles, and to this work he devoted the next four years. The longest railroad trestle bridge then in existence, 26 miles, carrying the road over Lake Pontchartrain and its marshes, was built under Mr. Nicholson's immediate charge. This short line of road involved other difficult and troublesome work quite out of proportion to the magnitude of the enterprise.

In 1885 Mr. Nicholson succeeded Mr. Bouscaren as Chief Engineer of the Cincinnati Southern and Associated roads, known then as the Queen and Crescent System. While changes in organization and in the constituent roads, which make up the present Queen and Crescent System, took place in the meantime, Mr. Nicholson continued to be its Chief Engineer until his death, retaining the unbounded confidence and friendship of every management. It is currently believed that during this time he was more than once offered promotion to higher executive departments, but no official confirmation of the fact is at hand, and Mr. Nicholson's extreme modesty prevented him from discussing such matters even with his intimate friends. It is known that outside positions, involving high honor and attractive compensation, were offered to him during this period, but he remained loyal to the road to which his services had become almost indispensable. Having been connected with the system since its inception, he knew every engineering and historical detail of its construction and operation, and could therefore serve the management far more efficiently than any new man who might be called to take his place.

His services, however, were not confined to the roads of which he had official charge. He was one of the trusted lieutenants of the late Samuel Spencer, President of the Southern Railway, of which the Cincinnati, New Orleans and Texas Pacific Railway is a part, and he was frequently called upon confidentially to examine and report upon important matters outside of his official jurisdiction.

To these, as well as to his own legitimate work, he applied and spent himself without reserve, and with little regard for his physical and mental welfare. Like others of his intense and conscientious temperament, he devoted his personal attention to many details which he might more wisely have referred to his assistants,

who were able and loyal. The late night, as well as the day, usually found him at his desk. The result was the too frequent one. The constitution that had carried him safely through the hardships and the physical stress of an unusually strenuous service in the Army, finally gave way under the later and greater mental and physical strain, and he found himself face to face with a nervous collapse. Early in 1906, against his will, he was directed by his superior officers to take a vacation. Returning from this, not much improved in health, his leave of absence was extended indefinitely, and he was persuaded to go abroad on full pay, with the hope that his health might be restored. This hope was not realized. His health continued to decline, and, returning late in November, 1906, he survived but a short time, dying on December 2d, 1906, in the home in Covington, Kentucky, he had so long occupied.

Of Mr. Nicholson's personal character and professional ability and attainments, it may be said that against his honor and integrity there was never a breath of suspicion. Considering the fact that his ordinary educational advantages were very limited, and that of technical school education and training he had none, his knowledge of the technical side of engineering was quite remarkable; but he was most noted for his sound practical sense and good judgment —the result of an able and alert mind backed by a wide experience. To his extreme modesty, amounting almost to shyness, in professional as well as in social affairs, must be attributed the fact that he appeard but seldom in the public eye.

No memoir of Mr. Nicholson, however brief, would be complete without some reference to his connection with "The Literary Club," of Cincinnati. This organization, founded in 1849, has been a notable center of literary culture in that city. Its membership list at any period, since its organization, has embraced the leading public, professional and literary men of the city and the surrounding region. In this list, past or present, may be found the names of one President of the United States, nine Generals of prominence in the United States Army, two United States Senators, three Governors of Ohio, seven Members of Congress, one Chief Justice of the United States, one distinguished actor, no less than three well-known poets, one Minister to Russia, and the present very able and honored Secretary of War.

Its meetings, held every Saturday night, when a paper is read, followed by a modest collation and an hour of social intercourse, may, without exaggeration, be characterized by the phrase, "A feast of reason and a flow of soul."

Mr. Nicholson became a member of this organization in 1885, and thereafter, until his death, was one of its most devoted and

useful members, serving as its President for two years, and for many years in other official capacities. In the cultured bonhomie of this club he found a congenial atmosphere in which the fine qualities of his mind and heart expanded into full flower. Next to his family and his work, this club and its interests occupied a front place in his mind and activities during the later part of his life. It is stated that "He contributed some twenty papers to the club, every one being a paper of merit." It was principally through his efforts that all the published works, numbering between 300 and 400, of those whose names appear on the membership list of the club since its organization, were collected into the club library.

The verdict of such a body of men as compose the membership of this club, upon the personal character and worth of Mr. Nicholson may be accepted as conclusive. The minute adopted by the club in his memory is, therefore, here in part quoted:

"His chief characteristics were integrity, a high sense of honor, modesty and unselfishness; the latter manifesting itself in a kindly interest, not only in people, but in the lower animals. If he encountered a tramp dog lying shivering on a cellar door, he would go out of his way to a chop house, buy food and carry it to the suffering creature.

"Everything he undertook to do he did well, he neglected nothing; and the only reward he valued was the consciousness of duty fulfilled and honor cherished. He had no itching greed for wealth nor social prominence, but enjoyed the amenities of life with his groups of friends with hearty good will. Owing to his devotion to his mother and sisters, and the children of one sister who was left in middle life with a dependent family, he never married.

"No one of us ever heard him refer to his military service, nor to any of the great achievements of his life. His modesty forbade; but he preserved all the records of his career as the safeguards of his honor. He felt, with Norfolk:

" 'Mine honor is my life;
Both grow in one;
Take honor from me,
And my life is done.'

"The exquisite charm of his friendship can be known only to those who enjoyed it; to them it was a benediction, and his death an irreparable loss."

Others who had the honor and pleasure to be numbered among his more intimate friends will fully endorse this estimate of his character.

Mr. Nicholson was elected a Member of the American Society of Civil Engineers on May 1st, 1878, took a keen interest in its affairs, and occasionally contributed to the discussion of papers read before it.

MERRITT HARRISON ROGERS, M. Am. Soc. C. E.*

DIED MAY 3D, 1907.

Merritt Harrison Rogers was born on May 19th, 1851, at Center Moreland, Pennsylvania, of one of the oldest New England families, his ancestors having been among the first settlers in Salem, Massachusetts.

He was educated at New Columbus Academy and Wyoming Seminary.

Mr. Rogers took part in the location and construction of several railroads in Pennsylvania, and in 1878 entered the service of the Kansas Pacific Railroad. In 1880 he became Transitman on the Denver and Rio Grande Railroad, and was appointed Assistant Engineer of that road in 1881 and Division Engineer in 1883, which position he held for six years. At that time the office of Chief Engineer was abolished, and Mr. Rogers was made Resident Engineer, with the duties and powers of Chief Engineer. Many extensions and improvements were made during this time.

In 1890, the office of Chief Engineer was revived, and Mr. Rogers was appointed to that position. In 1892 the superintendency of bridges and buildings was added to his duties.

In 1902 he retired and became a Consulting Engineer. At the end of two years he went to California for his health, and remained there a year. He returned to Colorado about a year ago and was appointed Chief Engineer of the Denver and Transcontinental Railroad. While going into the field to start a locating party for the season, he was stricken with apoplexy and died.

Mr. Rogers possessed the sterling qualities of his New England ancestors. He was of a high personal character, devoted to his friends and to his profession. He was an engineer of ability, and did much to develop the railroads of the West.

About twenty-two years ago he married Miss Mattie Dodge, of Buffalo, New York, who survives him. They had two children, but both died in infancy.

Mr. Rogers was elected a Member of the American Society of Civil Engineers on January 2d, 1890.

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* Memoir prepared by J. W. Deen, M. Am. Soc. C. E.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852.)

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President, GEORGE H. BENZENBERG.

Vice-Presidents.

Term expires January, 1908:
ONWARD BATES,
BERNARD R. GREEN.

Term expires January, 1909:
JOHN A. BENSEL,
JOHN A. OCKERSON.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOSEPH M. KNAP.

Directors.

Term expires January, 1908:
AUSTIN L. BOWMAN,
MORRIS R. SHERRERD,
HEZEKIAH BISSELL,
EDWIN A. FISHER,
WILLIAM B. LANDRETH,
GEORGE S. PIERSON.

Term expires January, 1909:
GEORGE GIBBS,
J. WALDO SMITH,
EMIL SWENSSON,
JAMES M. JOHNSON,
WYNKOOP KIERSTED,
WILLIAM B. STOREY, JR.,

Term expires January, 1910:
ALLEN HAZEN,
GEORGE W. TILLSON,
FRANK W. HODGDON,
JAMES CHRISTIE,
HORACE E. HORTON,
ARTHUR L. ADAMS.

Assistant Secretary, T. J. McMINN.

Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

On Finance:
JOHN A. BENSEL,
GEORGE GIBBS,
ALLEN HAZEN,
J. A. OCKERSON,
GEORGE S. PIERSON.

On Publications:
MORRIS R. SHERRERD,
ONWARD BATES,
BERNARD R. GREEN,
J. WALDO SMITH,
EMIL SWENSSON.

On Library:
GEO. W. TILLSON,
H. BISSELL,
JAMES CHRISTIE,
F. W. HODGDON,
CHAS. WARREN HUNT.

Special Committees.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, Richard L. Humphrey, George F. Swain, Alfred Noble, Louis C. Sabin, S. B. Newberry, Clifford Richardson, W. B. W. Howe, F. H. Lewis.

ON RAIL SECTIONS:—Joseph T. Richards, C. W. Buchholz, E. C. Carter, S. M. Felton, Robert W. Hunt, John D. Isaacs, Richard Montfort, H. G. Prout, Percival Roberts, Jr., George E. Thackray, Edmund K. Turner, William R. Webster.

ON CONCRETE AND REINFORCED CONCRETE:—C. C. Schneider, J. E. Greiner, W. K. Hatt, Olaf Hoff, Richard L. Humphrey, Robert W. Lesley, J. W. Schaub, Emil Swensson, A. N. Talbot, J. R. Worcester.

ON STATUS OF METRIC SYSTEM:—Stacy B. Opdyke, Jr., John Waterhouse, D. A. Molitor.

ON ENGINEERING EDUCATION:—Desmond FitzGerald, Benjamin M. Harrod, Onward Bates, D. W. Mead, Charles Hansel.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER......................5913 Columbus.
CABLE ADDRESS........................"Ceas, New York."

Vol. XXXIII. SEPTEMBER, 1907. No. 7.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

September 4th, 1907.—The meeting was called to order at 8.30 P. M.; Director A. L. Bowman, in the chair; Chas. Warren Hunt, Secretary; and present, also, 106 members and 12 guests.

The minutes of the meetings of May 15th and June 5th, 1907, and those held at the Thirty-ninth Annual Convention in Mexico, July 8th, 9th and 10th, 1907, were adopted as printed in *Proceedings*.

A paper entitled "Comparison of Rainfall and Run-Off in the Northeastern United States," by John C. Hoyt, Assoc. M. Am. Soc. C. E., was presented by the author.

The Secretary presented written discussions by E. C. Murphy, Assoc. M. Am. Soc. C. E., and Charles A. Holden, Assoc. Am. Soc. C. E., and the subject was further discussed by Professor Alfred J. Henry, of the U. S. Weather Bureau, and by Messrs. H. von Schon, Thaddeus Merriman, H. K. Barrows, and the author.

Ballots for membership were canvassed, and the following candidates elected:

AS ASSOCIATE MEMBERS.

GEORGE HILL BANKS, Houghton, Mich.
JOHN WILLIAM EBER, New York City
MILO STUART MACDIARMID, Detroit, Mich.
FREDERICK GARDINER SKINNER, Bethlehem, Pa.

The Secretary announced:

The transfer of the following candidates by the Board of Direction:

FROM ASSOCIATE TO ASSOCIATE MEMBER.

On June 4th, 1907:

AUGUSTUS VALENTINE SAPH, Berkeley, Cal.

FROM ASSOCIATE MEMBER TO MEMBER.

On September 3d, 1907:

JAMES CHURCHILL BOYD, New York City
WILLIAM HALE HAM, Youngstown, Ohio
JOHN THOMAS HENDERSON, Hartford, Conn.
ROBERT AUSTEN MCCULLOCH, New York City
WILLIAM SUTTON MCFETRIDGE, LaGrange, Me.
HENRY WRAY PRESTON, Elmira, N. Y.
WILLIAM JACKSON ROBERTS, Pullman, Wash.

The election of the following candidates by the Board of Direction:

AS JUNIORS.

On February 5th, 1907:

CHARLES RAY HAWLEY, Honey Grove, Tex.
LEO CHARLES O'BYRNE, Chicago, Ill.
JOHN LYNCH O'HEARN, Clinton, Okla.

On March 5th, 1907:

WILLIAM FRANKLIN MARTIN, Los Angeles, Cal.

On April 30th, 1907:

WILLIAM BARTLETT ATWOOD, Lima, Ohio
DANIEL EVERETT BELLOWS, Little Falls, N. Y.
ROBERT WALTER WOOD, West New Brighton, N. Y.

On June 4th, 1907:

FARRAND NORTHROP BENEDICT, Long Island City, N. Y.
PAUL DELMONT BUNKER, Key West Barracks, Fla.

Harry Chittenden Vensano, San Francisco, Cal.
John Robert Wilbanks, St. Louis, Mo.
Albert Jones Willis, South Bethlehem, Pa.

On September 3d, 1907:

Willard Seymour Brewer, Hartford, Conn.
George William Burpee, Brockton, Mass.
Lester Levi Carter, Vallecito, Cal.
Alden Brigham Cole, Carbondale, Pa.
Herbert Bismarck Foster, Berkeley, Cal.
James Augustine Galvin, Mechanicsville, N. Y.
Thomas MacLenathen Goodrich, Brooklyn, N. Y.
John Patrick Hurley, Mechanicsville, N. Y.
Harold Lord, Honolulu, Hawaii.
Adelbert Philo Mills, Ann Arbor, Mich.
William Watters Pagon, Baltimore, Md.
Birtram Willard Ranson, Boston, Mass.
Wilder Meloy Rich, Grand Rapids, Mich.
George Corliss See, Gloversville, N. Y.
Harry Shoemaker, Fort Edward, N. Y.
Mulford Stow, Troy, N. Y.
Alfred Lockwood Trowbridge, San Francisco, Cal.

The Secretary announced the following deaths:

Albert Johnstone Campbell, elected Associate Member, May 2d, 1894; died June, 1907.

Montague Sylvester Hasie, elected Member, February 3d, 1897; died May 30th, 1907.

Galen W. Pearsons, elected Member, January 6th, 1875; died August 19th, 1907.

Charles Francis Powell, elected Member, October 3d, 1888; died July 30th, 1907.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract)

September 3d, 1907.—President Benzenberg in the Chair; Chas. Warren Hunt, Secretary, and present, also, Messrs. Bowman, Gibbs, Knap, Noble, Schneider, Sherrerd, Smith, and Tillson.

The report of the Nominating Committee was received.

A committee to recommend the award of prizes for the year ending with the *Transactions* for July, 1907, was appointed.

Applications were considered, and other routine business transacted.

Seven Associate Members were transferred to the grade of Member, and seventeen candidates were elected as Juniors.

Adjourned.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, October 2d, 1907.—8.30 P. M.—Ballots for membership will be canvassed, and two papers will be presented for discussion, as follows: "Reinforced Concrete Towers," by D. W. Krellwitz, Jun. Am. Soc. C. E.; and "Reinforced Concrete Pipe for Carrying Water Under Pressure," by Chester Wason Smith, Assoc. M. Am. Soc. C. E.

These papers were printed in *Proceedings* for August, 1907.

Wednesday, October 16th, 1907.—8.30 P. M.—At this meeting a paper entitled "The Bracing of Trenches and Tunnels, With Practical Formulas for Earth Pressures," by J. C. Meem, M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for August, 1907.

Wednesday, November 6th, 1907.—8.30 P. M.—Ballots for membership will be canvassed, and a paper entitled "Water Purification at St. Louis, Mo.," by Edward E. Wall, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Society of Engineers, 17 Victoria Street, Westminster, S. W., England.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Civil Engineers' Club of Cleveland, 718 Caxton Building, Cleveland, Ohio.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa.

Engineers' Society of Western Pennsylvania, 803 Fulton Building, Pittsburg, Pa.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

Louisiana Engineering Society, 604 Tulane-Newcomb Building, New Orleans, La.

Engineers' Club of Central Pennsylvania, Corner Second and Walnut Streets, Harrisburg, Pa.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Teknisk Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Société des Ingénieurs Civils de France, 19 Rue Blanche, Paris, France.

Svenska Teknologföreningen, Brunkebergstorg 18, Stockholm, Sweden.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Pacific Northwest Society of Engineers, 617–618 Pioneer Building, Seattle, Wash.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Memphis Engineering Society, Memphis, Tenn.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

The Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Cleveland Institute of Engineers, Middlesbrough, England.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Rochester Engineering Society, Rochester, N. Y.

Brooklyn Engineers' Club, 197 Montague Street, Brooklyn, N. Y.

Montana Society of Engineers, Butte, Montana.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendix* to the Annual Report of the Board of Direction for the year ending December 31st, 1906, contains a summary of all searches made to that date.

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* *Proceedings*, Vol. XXXIII, p. 90 (January, 1907).

ACCESSIONS TO THE LIBRARY.

(From August 8th to September 10th, 1907.)

DONATIONS.*

SHAFT-SINKING UNDER DIFFICULT CONDITIONS.

By J. Riemer. Translated from the German by C. R. Corning and Robert Peele. Cloth, 9 x 6 in., illus., 13 + 176 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907. $3.00.

Various papers, dealing with this subject, have been issued from time to time by German mining engineers. These papers are brief and intended only for those who make a specialty of shaft-sinking. The author states that, for this book, he has revised and amplified these articles so as to adapt them to the use of mining engineers and students of mining engineering generally. The only methods explained at length are those which deal with shaft-sinking under difficult conditions. The method of sinking by hand is first discussed. This is followed by detailed descriptions of the boring system, the freezing process and drop-shafts, together with illustrated examples of each method. In the translators' preface it is stated that, while the subjects dealt with have been rather outside the practice of American mining engineers, on account of the more favorable conditions obtaining in this country, yet some of the methods of sinking described by the author, or an adaptation of them, are applicable and may be used by civil engineers in building deep foundations for heavy structures in watery soils. The Contents are: Shaft-Sinking by Hand; Shaft-Sinking by the Boring System; The Freezing Process; Drop-Shafts. There are nineteen plates and an index of two pages.

OPEN-HEARTH STEEL CASTINGS.

By W. M. Carr. Cloth, 8 x 5½ in., illus., 118 pp. Cleveland, Ohio, The Penton Publishing Company, 1907. $1.50.

On the title-page of this book, it is stated that it has been compiled from a series of articles written for and published by *The Iron Trade Review* and *The Foundry*. It is also explained that it is a complete exposition of the methods involved in the manufacture of open-hearth steel castings by the basic and acid processes. The Chapter headings are: Melting Stock for Acid Practice, Fuels and Alloys, Molding Materials, Materials for Basic Practice; Open-Hearth Furnace Construction; Fuels and Accessories; Manipulation of Heats in Acid Practice; Manipulation of Heats in Basic Practice, Order of Charging, Melting, Charging Cold Stock; Chemical Analyses and Physical Tests; Relation Between Composition and Physical Properties; Blow Holes in Steel Castings; Discussion of the Causes of Cracks in Steel Castings; Heat Treatment and Annealing; Repair of Steel Castings with Thermit; Cost of Equipment for Open-Hearth Steel Foundries. There is no index.

DESIGN AND CONSTRUCTION OF HYDRO-ELECTRIC PLANTS,

Including a Special Treatment of the Design of Dams. By R. C. Beardsley. Cloth, 9½ x 6½ in., illus., 7 + 512 pp. New York, McGraw Publishing Company, 1907. $5 net.

The subject is presented by the author in the order in which the various problems connected with the development of a complete water-power plant would be considered and studied by the practical engineer. These problems are discussed in detail, and cost items and data are included, which make the book valuable to teachers and students as well as to engineers and contractors. The principles of hydraulics are briefly explained in the first chapter, followed by a discussion on the measurement of the flow of water over weirs, dams, etc. Useful curves are included in this chapter with examples as to their use. The remainder of the book is devoted to a study of water-power plants, beginning with the preliminary investigations which should be made by the engineer as to the power of streams; a discussion of the suitability of various materials to be used in hydraulic construction follows, together with descriptions of methods and machinery used in such work. The design and construction of dams are discussed, together with the design and construction of power houses. Illustrations are given of well-known power plants, with designs for special conditions. Power-house equipment and the transmission of power are discussed in detail, and full descriptions of apparatus used in modern

*Unless otherwise specified, books in this list have been donated by the publisher.

practice are included. The book concludes with a chapter containing tables and formulas giving the power and energy of water under different conditions, etc. Many illustrations and tables are included, and there is an index of ten pages. The Contents are: Hydraulic Principles; Measurement of Flow; Reconnaissance of Water Power; Materials; Hydraulic Construction; Power House Construction; Power House Equipment; Power Transmission; Tables and Formulæ.

A TREATISE ON HIGHWAY CONSTRUCTION.

By Austin T. Byrne. Ed. 5, Rev. and Enl. Cloth, 9 x 6 in., illus., 43 + 1040 pp. New York, John Wiley & Sons, 1907. $5.00.

As stated in the secondary title, this book is designed for all who may be engaged in the location, construction, or maintenance of roads, streets and pavements. In the preface to this edition it is stated that considerable new matter has been added, enlarging the book by some 120 pages. The new matter consists of improved methods for testing paving materials; effects of motor vehicles on roads; results of experiments for the suppression of dust; use of asphaltic oil for the improvement of earth roads; and suggestions for the construction of roads adapted to modern traffic. There are added also statistics of capital invested in street pavements in the principal cities of the United States, with the *per capita* cost of maintenance. The Chapter headings are: Pavements; Materials Employed in the Construction of Pavements; Stone Pavements; Wood Pavements; Asphaltum and Coal-Tar Pavements; Brick Pavements; Broken-Stone Pavements; Miscellaneous Pavements; Foundations; Resistance to Traction; Location of Country Roads; Width and Transverse Contour; Earthwork; Drainage and Culverts; Bridges, Retaining-Walls, Protection Works, Tunnels, Fencing; City Streets; Footpaths, Curbs, Gutters; Reconstruction and Improvement of Country Roads; Maintenance, Repairing, Cleansing, and Watering; Trees; Staking out the Work; Specifications and Contracts; Implements and Prices; Miscellaneous Notes. There are four Appendices: Naming and Numbering Country Roads and Houses; Methods of Assessing the Cost of Street Paving; Ordinance Regulating the Width of Wagon-Tires; Cycle-paths; and an index of ninety-three pages.

Gifts have also been received from the following:

Aachen Kgl. Technische Hochschule. 1 pam.
Ala.-Chf. Mine Inspector. 1 pam.
Am. Foundrymen's Assoc. 1 pam.
Am. Inst. of Archts. 1 vol.
Berlin Kgl. Technische Hochschule. 1 pam.
Blanchard, A. H. 1 bound vol.
Brit. Fire Prevention Committee. 19 bound vol.
Buffalo, Rochester & Pittsburgh Ry. Co. 1 pam.
Cape of Good Hope-Colonial Secretary's Office. 3 pam.
Casares, David. 1 pam.
Central of Georgia Ry. Co. 1 pam.
Chanute, Octave. 1 pam.
Cincinnati, Ohio-Water Dept. 1 pam.
Conn.-State Highway Commr. 1 bound vol., 1 vol.
Corthell, E. L. 1 pam.
Eng. Soc., State Univ. of Iowa. 1 pam.
Eng. Soc., Univ. of Mich. 1 pam.
Fowler, C. E. 1 pam.
Glasgow, Scotland-Corporation Tramways. 1 pam.
Hannover Kgl. Technische Hochschule. 1 pam.
Hill, J. W. 1 pam.
India-Ry. Board. 1 pam.
Iron and Steel Inst. 1 bound vol., 1 vol.
Kimberly, A. E. 1 pam.
Lehigh Valley R. R. Co. 1 pam.
Long, Thos. J., Bequest. 75 bound vol., 5 vol., 186 pam., 52 specif., 3 maps and drawings, 3 blue prints.
Lynn, Mass.-Public Water Board. 1 pam.
McKeesport, Pa.-Board of Water and Lighting Comm. 1 pam.
Madras Presidency-Public Works Dept. 1 bound vol.
Manchester Steam Users' Assoc. 1 pam.
Marlborough, Mass.-Board of Water Commrs. 1 pam.
Mass.-Charles River Basin Comm. 1 pam.
Matamoros, L. 1 pam.
Michigan-State Board of Health. 1 bound vol.
Midland Ry. Co. 1 pam.
Minnesota R. R. and Warehouse Comm. 1 bound vol.
National Board of Fire Underwriters. 1 pam.
New Jersey-State Board of Health. 1 bound vol.
New South Wales-Govt. Statistician. 3 pam.
New South Wales-Met. Board of Water Supply and Sewerage. 1 bound vol.
New York City-Board of Water Supply. 2 vol.
New York City-Bureau of Buildings, Borough of Manhattan. 1 bound vol.
New York-State Engr. and Surveyor. 3 bound vol.
New York City Record. 1 bound vol.
Ontario-Provincial Board of Health. 1 bound vol.
Patton, W. B. 1 pam.
Providence, R. I.-City Engr. 1 pam.
Queensland-Water Supply Dept. 2 maps.
Ry. Equipment and Publication Co. 1 vol.
Rhode Island-State Commr. of Dams and Reservoirs. 1 pam.

Royal Soc. of Canada. 1 bound vol.
Smithsonian Institution. 1 bound vol., 1 vol.
Structural Assoc. of San Francisco. 21 nos.
Transvaal-Mines Dept. 2 vol.
U. S. Bureau of the Census. 1 bound vol.
U. S. Chief of Engrs. 14 specif.
U. S. Forest Service. 4 pam.
U. S. Lake Survey Office. 1 pam., 5 maps.
U. S. National Museum. 3 vol.
U. S. Office of Public Roads. 2 pam.
U. S. Public Health and Marine Hospital Service. 1 vol.
Western Ry Club. 1 bound vol.
Wilgus, W. J. 1 pam.
Wisconsin Univ. 1 vol.

BY PURCHASE.

Technical Year-Book, 1907; ed. by Arthur C. Kelly and Chas. Weekes. London, Percival Marshall & Co., 1907.

Swimming Pools. Their Construction; Mechanical Installation; Water Supply; Heating the Water; Various Types of Installations Adapted to Different Conditions; with Thirty Illustrations and Charts. By Jno. K. Allen. Chicago, Domestic Engineering, 1907.

Trow's General Directory, for the Year ending July 1st, 1908. New York, Trow Directory Company, 1907.

Forest Mensuration. By Henry Solon Graves. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907.

Drainage Problems of the East: Being a Revised and Enlarged Edition of "Oriental Drainage." By C. C. James. 2 Vol. Vol. 1, Text; Vol. 2, Plans. Bombay, The *Times of India* Office; London, 121 Fleet Street, 1906.

SUMMARY OF ACCESSIONS.

From August 8th to September 10th, 1907.

Donations (including 70 duplicates)	467
By purchase	6
Total	473

MEMBERSHIP.

ADDITIONS.

(August 9th to September 9th, 1907.)

MEMBERS.

		Date of Membership.
BEELER, JOHN ALLEN. Vice-Pres. and Gen. Mgr., The Denver City Tramway Co., 617 Majestic Bldg., Denver, Colo..		July 10, 1907
BOYD, JAMES CHURCHILL. With Westinghouse, Church, Kerr & Co., Engrs., 10 Bridge St., New York City	Jun.	Sept. 3, 1895
	Assoc. M.	May 1, 1901
	M.	Sept. 3, 1907
CLARK, ROSCOE NATHANIEL. Asst. City Engr., 800 Main St., Hartford, Conn	Assoc. M.	May 4, 1904
	M.	Mar. 5, 1907
HAM, WILLIAM HALE. Care, Gen. Fireproofing Co., Youngstown, Ohio	Assoc. M.	Nov. 5, 1902
	M.	Sept. 3, 1907
HAYWARD, ROBERT FRANCIS. Gen. Mgr., Mexican Light & Power Co., Ltd., City of Mexico, D. F., Mexico		July 10, 1907
HENDERSON, JOHN THOMAS. Deputy Chf. Engr., Conn. River Bridge and Highway Dist., Hartford, Conn	Assoc. M.	Sept. 3, 1902
	M.	Sept. 3, 1907
HOPSON, ERNEST GEORGE. Asst. Superv. Engr., U. S. Reclamation Service, 307 Tilford Bldg., Portland, Ore		July 10, 1907
MCFETRIDGE, WILLIAM SUTTON. Engr. of Constr., Bangor & Aroostook R. R., La Grange, Me	Jun.	May 3, 1898
	Assoc. M.	Mar. 4, 1903
	M.	Sept. 3, 1907
PRESTON, HENRY WRAY. Engr., Elmira Plant, Empire Bridge Co., Elmira Heights, N. Y.	Assoc. M.	May 3, 1899
	M.	Sept. 3, 1907

ASSOCIATE MEMBERS.

CARPENTER, CLARENCE EDSON. 33 Bruce Ave., Yonkers, N. Y.		July 10, 1907
DRANE, BRENT SKINNER. Box 89, Carlsbad, N. Mex		July 10, 1907
HARRIS, BORDEN BAKER. Office Engr., Philippine Railway Constr., Manila, Philippine Islands		April 3, 1907
HYDE, JOHN LAWRENCE. Asst. Town Engr., Westfield, Mass.		July 10, 1907
JUBB, SHERMAN AUGUSTUS. 3151 California St., San Francisco, Cal		Mar. 6, 1907
O'CONNOR, CORNELIUS JOSEPH. 1799 Washington Ave., Bronx, New York City	Jun.	Mar. 1, 1904
	Assoc. M.	June 5, 1907
THANHEISER, CHARLES AUGUST. Res. Engr., T. & N. O. R. R., Houston, Tex		July 10, 1907
VLIEGENTHART, JOHANNES CORNELIS. Haiho Conservancy, Tientsin, China		June 5, 1907
WILSON, THAD LOREN. Asst. Engr., Sewer Div., Rapid Transit Comm., 59 Pearl St., New York City		July 10, 1907
WOLCOTT, CHRISTOPHER STANTON. 1353 Pacific St., Brooklyn, N. Y		June 5, 1907

ASSOCIATES.

	Date of Membership.
LUNDBERG, JOHN HERVID. 1258 Bergen St., Brooklyn, N. Y.	April 3, 1907
THOMPSON, EDWARD PERCIVAL. Care, Philippine Products Co., Manila, Philippine Islands	June 5, 1907
VAN NAME, JOSEPH MASON. 1258 Bergen St., Brooklyn, N. Y.	April 3, 1907

JUNIORS.

BARLOW, ALFRED EUGENE, JR. 854 Lafayette Ave., Brooklyn, N. Y.	April 2, 1907
BROADHURST, WILLIAM GEORGE. 538 West 124th St., New York City	Sept. 3, 1907
BURPEE, GEORGE WILLIAM. P. O. Box 393, Brockton, Mass.	Sept. 3, 1907
MARTIN, WILLIAM FRANKLIN. 515 Merchants Trust Bldg., Los Angeles, Cal.	Mar. 5, 1907
MILLER, HENRY LANARK. Ferro Carril Central de Córdoba, Córdoba, Argentine Republic	June 4, 1907
SHOEMAKER, HARRY. Box 252, Fort Edward, N. Y.	Sept. 3, 1907

CHANGES OF ADDRESS.

MEMBERS.

BALDWIN, HENRY FURLONG. Chf. Engr., Oregon & Washington R. R. Co., Seattle, Wash.

BEACH, LANSING HOSKINS. Maj., Corps of Engrs., U. S. A., U. S. Engr. Office, Jacksonville, Fla.

BRACKENRIDGE, JOHN CROSBIE. Cons. Engr.; Pres., Rossiter, MacGovern & Co., 90 West St., New York City.

BROWN, EDWARD DU BOIS. Care, Fairbanks, Morse & Co., 12 Dey St., New York City.

CHAMBERS, RALPH HAMILTON. (Chambers & Hone), 15 William St., New York City.

FOSS, FRED EUGENE. Prof. of Civ. Eng. Practice, Carnegie Technical Schools, Pittsburg, Pa.

HARDING, CHESTER. Maj., Corps of Engrs., U. S. A., Gatun, Canal Zone, Panama.

HARMAN, EUGENE LEONARD. U. S. Asst. Engr. with Mississippi River Comm., 1307 Liggett Bldg., St. Louis, Mo.

HARWOOD, GEORGE ALEC. Chf. Engr., Electric Zone Impvts., N. Y. C. & H. R. R. R., 335 Madison Ave., Room 1206, New York City.

HUDSON, JOHN ROGERS. 1446 Blair Ave., St. Louis, Mo.

JACKSON, WILLIAM BENJAMIN. (D. C. & Wm. B. Jackson), 508 Commercial National Bank Bldg., Chicago, Ill.

KASTL, ALEXANDER EDWARD. Care, Board of Water Supply, Peekskill, N. Y.

KIMBALL, FRANK CLIFTON. 14 Beacon St., Boston, Mass.

KITTREDGE, GEORGE WATSON. Chf. Engr., N. Y. C. & H. R. R. R. Co., 335 Madison Ave., New York City.

MEMBERS (*Continued*).

LABELLE, HENRY FRANCIS. Care, N. M. C. S., Silver City, N. Mex.

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DEATHS.

BIRKS, ARTHUR HENRY. Elected Junior, April 5th, 1904; Associate Member, November 7th, 1906; died August 29th, 1907.

CAMPBELL, ALBERT JOHNSTONE. Elected Associate Member, May 2d, 1894; died June, 1907.

PEARSONS, GALEN W. Elected Member, January 6th, 1875; died August 19th, 1907.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(August 8th to September 10th, 1907.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal*, Assoc. Eng. Soc., 81 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Blk., Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.

(55) *Transactions,* Am. Soc. M. E., New York City, $10.
(56) *Transactions,* Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian,* London, England.
(58) *Proceedings,* Eng. Soc. W. Pa., 803 Fulton Bldg., Pittsburg, Pa., 50c.
(59) *Transactions,* Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering,* Indianapolis, Ind., 25c.
(61) *Proceedings,* Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World,* 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings,* Inst. C. E., London, England.
(64) *Power,* New York City, 20c.
(65) *Official Proceedings,* New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting,* London, England, 15c.
(67) *Cement and Engineering News,* Chicago, Ill., 25c.
(68) *Mining Journal,* London, England.
(70) *Engineering Review,* New York City, 10c.
(71) *Journal,* Iron and Steel Inst., London, England.
(72) *Electric Railway Review,* Chicago, Ill., 10c.
(73) *Electrician,* London, England, 18c.
(74) *Transactions,* Inst. of Min. and Metal, London, England.
(75) *Proceedings,* Inst. of Mech. Engrs., London, England.
(76) *Brick,* Chicago, Ill., 10c.
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(78) *Beton und Eisen,* Vienna, Austria.
(79) *Forscherarbeiten,* Vienna, Austria.
(80) *Tonindustrie-Zeitung,* Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen,* Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal,* Berlin, Germany.
(83) *Progressive Age,* New York City, 15c.
(84) *Le Ciment,* Paris, France.
(85) *Proceedings,* Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.
(86) *Engineering World,* Chicago, Ill.
(87) *Roadmaster and Foreman,* Chicago, Ill., 10c.

LIST OF ARTICLES.

Bridge.

The Proportioning of Steel Railway Bridge Members.* Henry S. Prichard. (58) July.
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Cost of Small Concrete Culverts.* Alex. R. Holliday, Assoc. M. Am. Soc. C. E. (13) Aug. 8.
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A Pile Trestle Erected with a Pivotal Pile-Driver.* R. Balfour. (13) Aug. 15.
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Electrical.

The Necaxa Plant of the Mexican Light and Power Company.* F. S. Pearson and F. O. Blackwell, Members, Am. Soc. C. E. (54) Vol. 58.
The Helion Lamp.* Walter G. Clark and Herschel C. Parker. (6) July.
Selenium Cells.* R. A. L. Snyder. (42) July.
Standardization Rules of the American Institute of Electrical Engineers. (42) July.
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The Use of Wooden Poles for Overhead Power Transmission.* C. Wade. (77) Aug.
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The Experimental Determination of the Losses in Motors.* Charles F. Smith. (77) Aug.
A New Leading-In Conductor for Electric Lamps.* C. O. Bastian. (77) Aug.
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The New Power Station of the South Metropolitan Electric Light and Power Co.* (26) Aug. 2.
The Production of High-Frequency Oscillations from the Electric Arc.* L. W. Austin. (Abstract from the *Bulletin* of the U. S. Bureau of Standards.) (73) Aug. 2.
On the Discharge of Condensers Charged by Transformers, and on the Regulation of Resonance Transformers.* A. Blondel. (Abstract from *L'Eclairage Electrique.*) (73) Aug. 2.
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On the Pupin Mode of Working Trunk Telephone Lines.* *Sir* William Preece. (Paper read before the British Assoc. for the Advancement of Science.) (73) Aug. 9.
Wireless Telegraphy—Some of Its Practical and Commercial Aspects. William Maver, Jr. (Paper read before the Assoc. of Ry. Telegraph Supts.) (19) Serial beginning Aug. 10.
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The 50 000-Volt Line of the Taylor's Falls-Minneapolis Power Transmission.* (27) Sept. 7.
Oil-Engine Driven Power Plant of the Pittsfield Electric Company.* (27) Sept. 7.
The Economy of the Tungsten Lamp.* Alfred A. Wohlauer. (27) Sept. 7.
The New York Edison Company's Scrap Heap.* (27) Sept. 7.
Outline of the Characteristics of Constant-Potential Transformers.* Geo. A. Burnham. (27) Sept. 7.
A 40 000-Volt Power Transmission in Lombardia.* (From *Electricity, Power and Gas.*) (24) Sept. 9.
Lifting Magnets and Their Numerous Industrial Applications.* (62) Sept. 9.
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Das Bohren und Nieten von Eisenkonstruktionen mit Elektrischen Pendelbohrmaschinen und Elektrischen Nietmaschinen.* W. Schrader. (82) Serial beginning Aug. 17.

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The "Typhonoid"—A New Type of Motor Boat.* M. J. Peltier. (46) Aug. 24.
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Etude de Quelques Procédés et Méthodes de Sauvetage et de Renflouage des Navires Sous-Marins. M. Dibos. (32) July.

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Modern Practice in Wire-Drawing Machines.* (11) Serial beginning Aug. 9.
Safety Appliances on Speed-Frames in Cotton-Mills.* (11) Aug. 9.
The Present Position of Gas and Petrol Engines.* Dugald Clerk, M. Inst. C. E. (Paper read before the British Assoc. for the Advancement of Science.) (73) Aug. 9; (Abstract.) (26) Aug. 9.
Relative Economy of Steam and Gas Power Where Exhaust Steam is Used for Heating. F. W. Ballard. (Paper read before the Ohio Soc. of Mech., Elec. and Steam Engrs.) (13) Aug. 15; (24) Sept. 2.
Report of Papers read before the Natural Gas Assoc. of America, at Joplin, Mo., May 21-23, 1907.* (83) Aug. 15.
High-Pressure Centrifugal Fans.* A. Rateau. (11) Serial beginning Aug. 16.
Ingot Heating Apparatus.* (12) Aug. 16.
The Stoneywood Paper Works.* (12) Aug. 16.
The Accuracy of Pressure Gauges. (22) Aug. 16.
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The Fuel-Testing Plant of the United States Geological Survey at the Jamestown Exposition.* (27) Aug. 17; (17) Aug. 10.
History and Construction of Steam Gauges.* C. E. Stromeyer. (47) Serial beginning Aug. 17.
The Rolling of Sheet Copper. Copperman. (20) Aug. 22.
Kirkwood Oil Burning Furnaces—An Installation at the Fort Wayne Shops of the Pennsylvania Lines West.* (20) Aug. 22.

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Notes on the Governing of Hydraulic Turbines.* Robert S. Ball. (Paper read before the British Assoc. for the Advancement of Science.) (11) Aug. 23.
Machine for Weighing the Forces on a Cutting Tool.* John F. Brooks. (Paper read before the British Assoc. for the Advancement of Science.) (11) Aug. 23.
The Latest Research on the Specific Heat of Superheated Steam.* Robert H. Smith. (12) Aug. 23.
Some New Steel Foundries.* (22) Aug. 23.
Gasoline 'Buses for New York.* (17) Aug. 24.
The Newman Kinematic Apparatus.* (19) Aug. 24.
Superheated Steam for Steam Turbines.* J. A. Moyer. (From the *Harvard Engineering Journal.*) (47). Aug. 24.
Compressed Air for Steam Hammers. Frank Richards. (62) Aug. 26.
Hot-Coke Conveying Plant at the Paris Gas-Works.* (66) Aug. 27.
The Illuminating Power in Ordinary and Incandescent Burners of Coal Gas, Water Gas, and Mixtures of the Two Gases. Emile Sainte-Claire Deville. (66) Serial beginning Aug. 27.
Some Recent Mechanical Coal Storage Plants.* Wilbur G. Hudson, M. Am. Soc. M. E. (13) Aug. 29.
Two-Stage Operation of a Large Pumping Engine.* A. O. Doane. (13) Aug. 29.
Recent Heavy Cranes in English Shops.* (13) Aug. 29.
Rolling Seamless Tubes.* (20) Aug. 29.
Remarks on Pressure-Gauges.* C. E. Stromeyer. (Abstract) (11) Aug. 30.
Modern Machinery and Its Future Development.* H. J. Brackenbury. (Paper read before the British Assoc. for the Advancement of Science.) (12) Aug. 30; (11) Aug. 30.
Influence of the Lurmann Cinder Notch on the Working of the Blast Furnace.* (22) Aug. 30.
Improved Methods of Dust Prevention in the Grinding Trades.* Samuel R. Bennett. (29) Aug. 30.
The Choice of a Bituminous Coal.* R. H. Kress. (14) Aug. 31.
Electrical Machinery Used in Coke Operations. (14) Aug. 31.
A New Development in Air Compressors.* Frederick A. Halsey. (From the *American Machinist.*) (16) Aug. 31.
Gas Engine Breakdowns.* Michael Longridge. (47) Aug. 31.
A Few Notes on Results of Tests of Worn Ropes. W. Martin Epton. (Paper read before the Transvaal Inst. of Mech. Engrs.) (68) Aug. 31.
The Comparative Cost of Steam and Hydro-Electric Power.* William O. Webber. (9) Sept.
The Growth and Development of the Elevator Industry.* Charles H. Kloman. (10) Sept.
The Flash Steam Generator.* H. W. Bolsover. (10) Sept.
Boiler-Room Design and Equipment.* Wm. H. Bryan, M. Am. Soc. M. E. (10) Sept.
Autogenous Welding.* F. C. Cutler. (10) Sept.
Physical Properties of Saturated Steam.* Fred R. Low. (64) Sept.
Indicator Diagrams from a Canadian Crude-Oil Engine.* H. Addison Johnston. (64) Sept.
Mains and Fittings for Gas-Power Plants. L. L. Brewer. (64) Sept.
Pressures and Work in a Gas Engine.* Cecil P. Poole. (64) Sept.
Test of Tube-Connected Cylinders.* S. F. Jeter. (64) Sept.
The Manufacture of Peat-Fuel in Michigan—Description of the "Wet Process."* Francis J. Bulask. (64) Sept.
Improvements in the Vertical-Plunger Sinking Pump.* A. H. Hale. (64) Sept.
Best Method of Supplying Oil to Turbines.* Thomas Franklin. (64) Sept.
Saving Exhaust Steam from an Intermittently Running Engine.* (64) Sept.
Rigid and Other Joints.* H. W. (From the *Gas World.*) (24) Sept. 2.
Acetylene Lighting.* Nelson Goodyear. (Paper read before the Illuminating Eng. Soc.) (83) Sept. 2.
Everit Tar-Naphthalene Extractor.* J. D. Smith. (Paper read before the North British Assoc. of Gas Mgrs.) (83) Sept. 2.
Use of By-Product Coke Oven Gas. C. E. Rhodes. (Abstract from paper read before the Inst. of Gas Engrs.) (83) Sept. 2.
Hot Water Boiler Washing. (Abstract of Committee Report to Traveling Engrs.' Assoc.) (18) Sept. 7; (40) Sept. 6.
Manufacture of Boiler Tubes. F. N. Speller. (Paper read before the Richmond Ry. Club.) (18) Sept. 7.
Engine Driven Centrifugal Pumps: Their Capacities, Limitations and Duties.* (18) Sept. 7.
Oil-Engine Driven Power Plant of the Pittsfield Electric Company.* (27) Sept. 7.
Formule Relative a une Condition de Stabilité des Automobiles et Spécialement des Autobus: Oscillations Diverses.* Georges Marie. (32) June.
L'Art de Couper les Métaux.* C. Condron. (37) Serial beginning July 31.
Théorie de l'Autoloc.* L. Lecornu. (37) July 31.
L'Exactitude de la Formule de Rankine et l'Influence des Encastrements dans les Longues Pièces Comprimées.* Gustave L. Gérard. (30) Aug.

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Moutons à Courroies, Système Dieudonné-Lechêne.* (34) (Abstract.) Aug.
Compresseur d'Air Compound à Double Compression.* Jean Grégoire. (34) Aug.
Extinction et Manutention du Coke dans les Usines à Gaz; Extinction et Transport par un Courant d'Eau.* A. Thibeault. (33) Aug. 3.
Le Coupage des Métaux par l'Oxygène.* Leon Guillet. (33) Aug. 10.
Le Problème de l'Aviation et la Résistance de l'Air.* E. Maleire. (33) Serial beginning Aug. 10.
La Manutention Mécanique dans les Journaux et dans les Papeteries.* Ch. Dantin. (33) Aug. 17.
Die Bearbeitung der Ringschmierlager.* C. Volk. (48) Aug. 10.
Die Nebenspannung in Rasch Umlaufenden Scheibenrädern.* A. Stodola. (48) Aug. 10.
Ueber Wassergas.* H. Dicke. (50) Serial beginning Aug. 14.
Kreiselgebläse für Hohen Druck.* A. Rateau. (48) Aug. 17.
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Metallurgical.

Copper Steels.* Pierre Breuil. (71) Vol. 74.
Cast Iron as Cast and Heat Treated.* W. H. Hatfield. (71) Vol. 74.
The Non-Metallic Impurities in Steel.* E. F. Law. (71) Vol. 74.
Boron Steels.* Leon Guillet. (71) Vol. 74.
Address on the Effect of Air and Moisture on Blast-Furnaces, Delivered at Bradford (England), June 11, 1800. Joseph Dawson. (71) Vol. 74.
Eighth Report to the Alloys Research Committee: On the Properties of Alloys of Aluminium and Copper.* H. C. H. Carpenter and C. A. Edwards. (75) Mar., 1907.
The Treatment of Zinc Ores in Colorado.* F. W. Traphagen. (45) Aug.
The Washoe Smelter.* (45) (Abstract.) Aug.
The Betts Process at Trail, B. C.: Electrolytic Refining of Lead Bullion. Treatment of Gold and Silver Slimes, Copper Sulphate Recovery.* A. G. Wolf. (Paper read before the Western Assoc. of Technical Chemists and Metallurgists.) (45) Aug.
Malleable Castings.* E. L. Rhead. (47) Serial beginning Aug. 3.
Experiments with Cylinder Irons. R. Buchanan. (Abstract of paper read before the Cleveland (England) Inst. of Engrs.) (22) Aug. 9.
Electric Tempering Furnaces. (Tr. from *L'Elettricita.*) (68) Aug. 17.
Magnetic Concentration of Iron Ores by the Gröndal Process. (Abstract of paper read before the Canadian Min. Inst.) (22) Aug. 23.
The Nordberg Compound Steam Stamp.* (16) Aug. 24.
Manganese in Cast Iron. Herbert E. Field. (Paper read before the Amer. Foundrymen's Assoc.) (47) Aug. 24.
Mining and Smelting at Granby, Missouri.* Edwin T. Perkins. (16) Aug. 31.
Goldschmidt Thermit Steel Valuable for Welding Purposes.* (62) Sept. 2.
Influence of Iron in Copper Electrolysis. E. L. Larison. (16) Sept. 7.
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Chariot à Commande Hydro-Electrique pour Porche de Coulée de 20 Tonnes.* (33) Aug. 17.
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Ueber den Gegenwärtigen Stand der Schlagbiegeprobe mit Eingekerbten Stäben. (50) Serial beginning July 31.

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The Dynamics of Long Recoil.* A. G. Greenhill. (12) Aug. 23.

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Bituminous Coal Washing. G. R. Delamater. (45) Serial beginning Aug.
Notes on Hydraulic Mining, With Special Reference to the Cariboo District, British Columbia, and Yukon Territory.* (45) Aug.
Recent Testing of Coal Used by the Federal Government in its Public Buildings at Washington, D. C.* J. A. Holmes and D. T. Randall. (45) Aug.
The Daly-Judge Mine and Mill, Park City, Utah.* Paul A. Gow and others. (Abstract.) (45) Serial beginning Aug.
Colliery Warnings. (57) Aug. 9.
The Black Sand Problem.* F. Powell. (16) Aug. 10.
Mining Methods on the Gogebic Iron Range.* Reginald Meeks. (16) Aug. 10.
Ground Breaking in the Joplin (Mo.) District.* Doss Brittain. (16) Aug. 10.
The Ultimate Crushing Strength of Coal.* Joseph Daniels and L. D. Moore. (16) Aug. 10.
The Nomenclature of Modern Placer Mining.* J. P. Hutchins. (16) Aug. 10.

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A Mine Dam to Recover Flooded Workings.* John H. Haertter. (16) Aug. 10.
Fighting a Colliery Fire. W. H. Pickering and R. R. Simpson. (Abstract of paper read before the Min. and Geological Inst. of India.) (22) Aug. 16.
Electrical Winding Plant at Mattias Stinnes Colliery. D. Selby-Bigge. (Abstract of paper read before the South Wales Inst. of Engrs.) (22) Aug. 23.
The Essential Data of Placer Investigation.* J. P. Hutchins. (16) Serial beginning Aug. 24.
A Cripple Creek Ore-Handling Plant.* S. A. Worcester. (16) Aug. 24.
Mining and Smelting at Granby, Missouri.* Edwin T. Perkins. (16) Aug. 31.
Setting Timber in Anthracite Coal Mines.* John H. Haertter. (16) Aug. 31.
The Effect of Barometric Variation on the Outflow of Gas in Mines. W. H. Booth. (16) Aug. 31.
Care of Mine Mules.* I. C. Newhard. (Abstract.) (45) Sept.
Mining Conditions in South Africa.* J. B. Pitchford. (Lecture delivered before the Mining Students of the Univ. of California.) (45) Sept.
Mining at Bingham, Utah.* Robert B. Brinsmade. (45) Serial beginning Sept.
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Concrete Overcasts in Coal Mines.* John H. Haertter. (16) Sept. 7.
Mining the Porphyry Ore of Bingham (Utah).* Walter Renton Ingalls. (16) Sept. 7.
Possibilities of Electricity in Metal Mining.* G. M. Dyott. (27) Sept. 7.

Miscellaneous.

The Engineer as a Professional Man: (Presidential) Address at the Annual Convention (Am. Soc. Civ. Engrs.), City of Mexico, July 8th, 1907. George H. Benzenberg, President, Am. Soc. C. E. (54) Vol. 58.
Engineers' Contracts and Specifications from a Contractor's Point of View. James W. Rollins, Jr. (1) July.
Illumination Photometers and Their Use.* Preston S. Millar. (Paper read before the Illuminating Eng. Soc.) (24) Aug. 19.
The Library System of Stone & Webster. (14) Aug. 24.

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The Application of Tar to Macadamized Roads. Thomas Aitken. (Abstract of paper read before the Assoc. of Municipal and County Engrs.) (13) Aug. 22.
The Asphalt Pavement on the Thames Embankment.* (14) Aug. 24.
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Tarring Road Surfaces. J. W. Howard. (Abstract of paper read before the Amer. Road Makers' Assoc.) (83) Sept. 2.

Railroad.

Uniformity of Requirement and Clearness of Specification in Agreements for the Graduation of Railroads. W. F. Dennis, M. Am. Soc. C. E. (54) Vol. 58.
Some Facts and Problems Bearing on Electric Trunk-Line Operation.* Frank J. Sprague. (42) July.
Single-Phase Versus Three-Phase Generation for Single-Phase Railways.* A. H. Armstrong. (42) July.
The Choice of Frequency for Single-Phase Alternating-Current Railway Motors.* A. H. Armstrong. (42) July.
Twenty-five Versus 15 Cycles for Heavy Railways. N. W. Storer. (42) July.
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Siemens Bros. "All-Electric" Signalling and Interlocking Plant.* (21) Serial beginning Aug.
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Heating and Ventilating of Cars.* E. R. Swan. (Paper read before the Amer. Soc. of Heating and Ventilating Engrs.) (76) Aug.
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Rail Motor-Cars. (Abstract of report made to the Amer. Master Mechanics' Assoc.) (47) Aug. 10.
Standard Turntable Pit: Seaboard Air Line Ry.* Philip Aylett, Assoc. M. Am. Soc. C. E. (13) Aug. 15.
Center-Bound Track as a Cause of Spreading Rails. (Abstract of paper in *The Technograph*, Vol. XXI, 1906-07.) (13) Aug. 15.
Test Track of the Prussian State Railways.* (15) Aug. 16.
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Steel Rails of Better Quality. Robert Job. (20) Aug. 22.
Note on the Economic Renewal and Maintenance of Railway Tracks for High-Speed Traffic.* L. Schlüssel. (Abstract fr. *Bulletin,* Inter. Ry. Cong. Assoc., Apr., 1907.) (12) Aug. 23.
A Note on Compound Locomotives.* Maurice Demoulin. (12) Serial beginning Aug. 23.
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The Atlantic Shore Line Railway.* (72) Aug. 24.
Some Cost Figures on Forest Planting for Railroad Purposes. E. A. Sterling. (13) Aug. 29.
Construction of Second Track Accompanied by Reduction of Gradient. H. H. Knowlton. (Abstract of paper in the *Purdue Engineering Review.*) (13) Aug. 29.
Causes of Leaks in Locomotive Boiler Tubes.* M. E. Wells. (Abstract of paper read before the Amer. Railway Master Mechanics' Assoc.) (13) Aug. 29.
Solid Steel Wheels for Passenger Cars. George L. Fowler. (Abstract of discussion before the Master Car Builders' Assoc.) (20) Aug. 29.
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Rainfall and Run-Off in Storm-Water Sewers.* Charles Emerson Gregory, Assoc. M. Am. Soc. C. E. (54) Vol. 58.
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Administration of Pennsylvania Laws Respecting Stream Pollution. F. Herbert Snow. (58) July.
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Heating and Ventilating a Group of Public Schools.* S. R. Lewis. (Paper read before the Amer. Soc. of Heating and Ventilating Engrs.) (76) Aug.

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Sewage Experiments at Matunga, Bombay.* Gilbert J. Fowler. (13) Aug. 8.
Work at the Madeleine Sewage Experiment Station, Pasteur Institute of Lille, France. Earle B. Phelps. (13) Aug. 15.
Relative Economy of Steam and Gas Power Where Exhaust Steam is Used for Heating. F. W. Ballard. (Paper read before the Ohio Soc. of Mech., Elec. and Steam Engrs.) (13) Aug. 15.
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The Revised Sanitary Code of the Town of Montclair, N. J. (13) Aug. 22.
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Constructing a Sewer Under the Brooklyn Subway.* (14) Aug. 31.

Structural.

The Fatigue of Concrete.* J. L. Van Ornum, M. Am. Soc. C. E. (54) Vol. 58.
The Proposed Testing Laboratory of the Department of Civil Engineering (Columbia University).* William H. Burr. (6) July.
Method of Constructing the Foundations for the Trust Company of America Building, New York City.* Maurice Deutsch. (6) July.
A Briquette Testing Machine of the Pendulum Type.* H. F. Moore. (67) Aug.
The Open-Tank Method for Treatment of Timber.* (Abstract from Circular No. 101, Forest Service, U. S. Dept. of Agri.) (87) Aug.
Priming Coats for Metal Surfaces: Linseed Oil *vs.* Paint. F. P. Cheesman. (Abstract of paper read before the Amer. Soc. for Testing Materials.) (13) Aug. 8.
Cost of Shop Drawings for Structural Iron and Steel. Ralph H. Gage. (Abstract of paper from *The Technograph*, No. 21, 1906-07.) (13) Aug. 8.
Standard Specifications for Structural Timber: Amer. Soc. for Testing Materials. (15) Aug. 9.
Tests of Concrete Columns.* Arthur N. Talbot. (Paper read before the Amer. Soc. for Testing Materials.) (14) Aug. 10.
The New Warehouse of the Newark Warehouse Company.* (14) Aug. 10.
Investigation of the Thermal Conductivity of Concrete and Embedded Steel and the Effect of Heat Upon Their Strength and Elastic Properties.* Ira H. Woolson. (Paper read before the Amer. Soc. for Testing Materials.) (13) Aug. 15.
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Tension Tests of Steel Angles with Various Types of End-Connection.* Frank P. McKibben. (Paper read before the Amer. Soc. for Testing Materials.) (13) Aug. 22.
Ferro-Concrete and Examples of Construction. J. S. E. De Vesian, M. Inst. C. E. (Paper read before the British Assoc. for the Advancement of Science.) (22) Aug. 28.
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Symmetrical Masonry Arches, Coefficients for Reactions and Moments at the Supports. Malverd A. Howe. (15) Aug. 30.
The Electrolytic Theory of the Corrosion of Iron. Allerton S. Cushman. (19) Serial beginning Aug. 31; (20) Aug. 8.
The Design and Construction of Industrial Buildings.* D. C. Newman Collins. (9) Sept.
Steel Sheet Piling. (62) Sept. 2.
Fall of a 150-Ft. Reinforced Tile-and-Concrete Chimney at La Crosse, Wis.* (13) Sept. 5.
Effect of Steam Curing on the Crushing Strength of Concrete.* (13) Sept. 5.
A Combined Underpinning and Sheeting Job (Murray Street Building, New York City).* (14) Sept. 7.
The New Manufacturing Plant of the George N. Pierce Co., Buffalo, N. Y.* (14) Sept. 7.
The Erection of the 612-Foot Singer Building.* (46) Sept. 7.
Moving the Montauk Theatre.* (46) Sept. 7.
Le Glissement des Armatures. (84) July.
Etude d'un Phénomène de Dissociation de Mortier de Ciment par Infiltration d'Eau. (84) Serial beginning July.
Le Calcul des Flèches des Poutres par l'Intégration Graphique.* E. Aragon. (33) Serial beginning Aug. 17.
Fundierung und Grundwasser-Abdichtung für den Erweiterungsbau der Bank für Handel und Industrie zu Berlin.* Th. Gesztessy. (78) Aug.

*Illustrated.

Structural—(Continued).

Vergleichende Kostenberechnung der Eisenarmierung aus Biegungsfesten Profileisen und aus Stabeisen für Verbundbalken von Grösserer Stützweite.* Weidmann. (78) Aug.

Angebliche Haftfestigkeitsunterschiede bei Kalksandsteinen und Ziegeln. Prof. Germer. (80) Aug. 1.

Die Ergebnisse der Probebelastung Durchgehender mit den Unterstützenden Trägern Zusammenhängender Platten.* Koenen. (Paper read before the Deutscher Beton-Verein E. V.) (80) Aug. 1.

Ueber die an der k. k. Forstlichen Versuchsanstalt Mariabrunn Gewonnenen Resultate der Holzfestigkeitsprüfungen.* Gabriel Janka. (53) Serial beginning Aug. 9.

Versuch über die Schubwirkung bei Eisenbeton. Emil Mörsch. (Paper read before the Deutscher Beton-Verein E. V.) (80) Aug. 10.

Topographical.

History of Map Making and Topography.* C. W. Larned. (19) Serial beginning Aug. 24.

Water Supply.

Recent Practice in Hydraulic-Fill Dam Construction.* James D. Schuyler, M. Am. Soc. C. E. (54) Vol. 58.

The Design of the New Croton Dam.* Edward Wegmann, M. Am. Soc. C. E. (54) Vol. 58.

Additional Information on the Durability of Wooden Stave Pipe.* Arthur L. Adams, M. Am. Soc. C. E. (54) Vol. 58.

Hydraulic Formulæ: Development and Discussion.* Adolph Black. (6) July.

Pumping Machinery for Dalny Water-Works.* (12) Aug. 2.

New Water Purification Plant at Exeter, N. H.* Robert Spurr Weston. (13) Aug. 8.

Experiments with a Jewell Filter at the Posen Water Works. E. A. Gieseler. (14) Aug. 10.

A Reinforced Concrete Water Tower at Anaheim (Cal.).* (14) Aug. 14.

Comparative Costs of Gasoline, Gas, Steam and Electricity for Small Powers.* William O. Webber. (13) Aug. 15.

Cleaning an 8-In. Cast-Iron Water Main in Pittsburg, Pa.* J. D. Underwood. (13) Aug. 15.

Electrically-Operated Water-Works of Tacoma, Wash.* H. Cole Estep. (27) Aug. 17.

A New Egyptian Irrigation Canal.* J. B. Van Brussel. (46) Aug. 17.

Some Notes on Oriental Water-Works. George A. Johnson. (Paper read before the Amer. Water-Works Assoc.) (14) Aug. 24.

A Buttressed Concrete Dam.* (14) Aug. 24.

The Wood-Stave Pipe Line of the Madison River Power Company.* W. E. Belcher. (16) Aug. 24.

Movable Crest Dams at the Water Power Development of the Chicago Drainage Canal.* (14) Aug. 24.

Reconstructing a Masonry Dam for Increased Depth of Storage.* (13) Aug. 29.

Irrigation in Western Canada. (11) Aug. 30.

Speed Regulation for High-Head Water-Wheels. (14) Aug. 31.

The Water Purification and Softening Works at New Orleans, La.* (14) Aug. 31.

An Infiltration Water-Works Intake Under the Ohio River.* (14) Aug. 31.

Direct and Indirect Methods of Electrical Purification of Water.* Henry Leffmann. (3) Sept.

The Comparative Cost of Steam and Hydro-Electric Power.* William O. Webber. (9) Sept.

The Water Filtration Plant at Harrisburg, Pa.* (60) Sept.

Forests and Run-Off. (14) Sept. 7.

The Hydro-Electric Development of the Great Northern Power Co.* (14) Serial beginning Sept. 7.

A 7-Ft. Steel Pipe Line at St. Louis.* (14) Sept. 7.

The Detection of Pollution in Underground Waters. John C. Thresh. (Abstract of paper read before the Assoc. of Water Engrs.) (14) Sept. 7.

Ueber den Freien Ausfluss von Flüssigkeiten an Mündungen bei Unvollkommener Kontraktion. A. Jarolimek. (53) Aug. 9.

Waterways.

The Naval Floating Dock—Its Advantages, Design and Construction.* Leonard M. Cox, M. Am. Soc. C. E. (54) Vol. 58.

Lighthouse Construction in the Philippines.* Spencer Cosby, M. Am. Soc. C. E. (54) Vol. 58.

The Atchafalaya River: Some of Its Peculiar Physical Characteristics.* J. A. Ockerson, M. Am. Soc. C. E. (54) Vol. 58.

Twenty Years' Run-Off, at Holyoke, Mass., of the Connecticut River. Clemens Herschel, M. Am. Soc. C. E. (54) Vol. 58.

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*Illustrated.

Waterways—(Continued).

Floods and Means of Their Prevention in Our Western Rivers. T. P. Roberts. (58) July.

Failure of Masonry Arch Carrying Erie Canal over Onondaga Creek, Syracuse, N. Y.* (13) Aug. 8.

Destruction of Debris Barrier No. 1, Yuba River, California.* E. C. Murphy, Assoc. M. Am. Soc. C. E. (13) Aug. 8.

The Locust Point Pier Collapse in Baltimore.* (13) Aug. 8.

The Ice Problem in Engineering Work in Canada.* Howard T. Barnes. (Paper read before the British Assoc. for the Advancement of Science.) (11) Aug. 9.

Sea Defence Works at Hornsea (England).* (12) Aug. 9.

New Entrance Channel at Saint Nazaire.* (12) Aug. 9.

Submarine Signalling.* (12) Aug. 16.

The Contractor's Plant and Methods on the Harbor Work at Gary, Ind.* (14) Aug. 17.

Stone Breakwater Construction at Huron, Ohio.* Wilson T. Howe. (13) Aug. 22.

Water Level Gages.* Robert E. Horton, Assoc. M. Am. Soc. C. E. (13) Aug. 22.

The Land and Water Terminal of the Seaboard Air Line Railway at Savannah, Ga.* W. D. Faucette. (Abstract of paper read before the Associated Engr's. and Constructor's Soc. of Tidewater, Va.) (13) Aug. 22.

Southern Appalachian Streams.* Charles E. Waddell. (3) Sept.

The Launch of the Caissons Recently Built at the Norfolk Navy Yard.* (46) Sept. 7.

Les Observations de Courants à Zeebrugge.* Urbain et Allaeys. (30) Aug.

Ueber Konstruktion und Berechnung von Kaimauern mit Hinterlast.* H. Zuckschwerdt. (8) Vol. 4, 1907.

Die Erweiterung des Kaiser Wilhelm-Kanales.* Scholer. (Paper read before the Verband Deutscher Architekten- und Ingenieur-Vereine in Kiel.) (51) Aug. 24.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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WATER PURIFICATION AT ST. LOUIS, MO.

BY EDWARD E. WALL, M. AM. SOC. C. E.

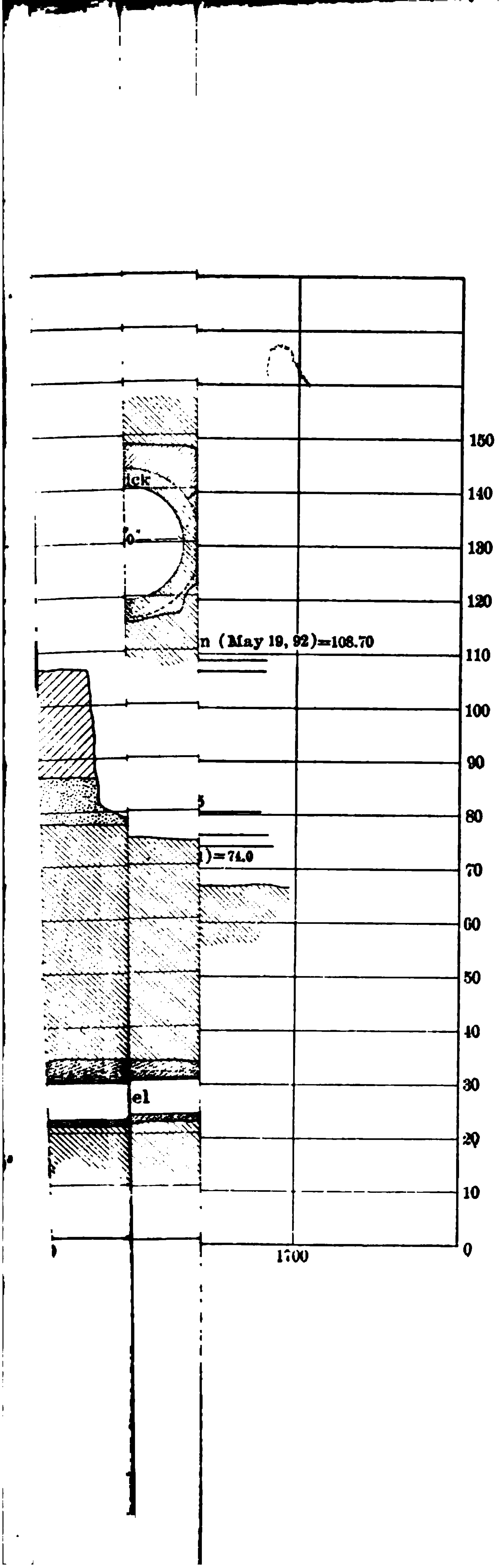
TO BE PRESENTED NOVEMBER 6TH, 1907.

Previous to 1904, St. Louis was famous for the muddy water supplied to its inhabitants and visitors. The inhabitants, never having known anything else, had ceased to pay attention to the appearance of the water, accepting it as a matter of course, just as they endured the wind and the weather, and were inclined to be amused at "the stranger within their gates," who protested against drinking and bathing in the coffee-colored fluid. Visitors to St. Louis in the summer and autumn of 1904, who had previously been in the city, were amazed to find clear, sparkling water in general use even for sprinkling and street washing. The history of events leading up to this sudden and remarkable change in the water supply of St. Louis, and a description of the purification process as finally developed and used, cannot fail to be of interest to engineers, especially to those engaged on water-works and in the investigation of water supplies.

In May, 1903, Mr. Ben C. Adkins was made Water Commissioner of St. Louis, and the writer was appointed by him as Principal As-

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

PLATE LXXV.
PAPERS, AM. SOC. C. E.
SEPTEMBER, 1907.
WALL ON
WATER PURIFICATION AT ST. LOUIS, MO.



LOW SERVICE EXTENSION
PROFILE OF TUNNEL LINE
AT
CHAIN OF ROCKS

sistant Engineer, the position of Assistant Water Commissioner being created later.

The most important question confronting the Department at that time was to devise some method of improving the appearance of the water, which should be of such design that it could be put into operation previous to the opening of the World's Fair, that is, in less than one year.

A brief description of the water-works will be necessary in order that the conditions existing at that time, and the changes that were afterward made, may be understood. The water supply of St. Louis is taken from the Mississippi River at the Chain of Rocks, about ten miles above the Eads Bridge, which spans the river approximately at the center of the city. The intake tower stands near the middle of the river, resting on bed-rock and built over a 7-ft. shaft leading down to a tunnel some 50 ft. below the river bed. This tunnel is also 7 ft. in diameter and terminates at the river bank at the base of the uptake shaft, which connects the river and the shore tunnels. The shore tunnel, also 7 ft. in diameter, is about 30 ft. nearer the surface than the river tunnel, and ends at the wet well from which the low-service pumps take their supply. (Plate LXXV.)

The low-service pumps deliver the water to a well at the head of a 9 by 11-ft. horseshoe-shaped conduit, which runs along the ends of a series of six settling basins, each 400 by 670 ft., with connections and gates for filling each basin separately. At the opposite ends of these basins is another 9 by 11-ft. conduit with connections to each basin for drawing off the water. This drawing conduit carries the water to the high-service stations several miles below. (Fig. 1.)

Previous to 1903, the operation of the settling basins consisted in a separate filling and drawing of each basin, allowing as long a time as possible for settlement before drawing off the water for delivery to the high-service pumps. This time usually varied from 12 to 24 hours, during which the heaviest and coarsest portion of the suspended matter fell to the bottom, but so much finely divided matter remained in suspension that the casual observer could scarcely notice any difference between the river water and that delivered to the consumer.

The river water carries in suspension amounts varying from 20 to 6 000 parts per million, according to the stage of the river, the solids in solution varying from 140 to 400 parts per million, the bacteria ranging from 2 000 to 250 000 per cu. cm.

The method of simple sedimentation reduced the suspended solids from 10 to 80%, the number of bacteria being reduced probably in the same ratio, but was eminently unsatisfactory because of the low percentage of improvement and the scarcely perceptible change in the appearance of the water.

The problem of devising a better system of clarifying and purifying the water supply of St. Louis had been studied and discussed by the best hydraulic engineers in the country. Filtration plants at home and abroad had been examined and studied, and various projects had been offered as solutions of the problem. For 40 years the question had occupied a prominent place in all propositions connected with the improvement and extension of the water-works. All proposed schemes for clarifying and purifying the water supply, which were worthy of serious consideration, involved the expenditure of millions, and necessitated the building of works which would take years to complete.

Many years ago it was proposed to abandon the Mississippi River as a source of supply and to go some 90 miles away to the Meramec Springs. Another proposition was to move the intake to the Missouri River above St. Charles, Mo. These schemes contemplated furnishing the water to the city by gravity flow, the Meramec project involving the construction of an immense impounding reservoir with miles of masonry conduit, steel pipe and tunnels, while the Missouri River plan required the building of a new low-service pumping station to deliver water to a set of new basins to be constructed on high ground a few miles outside the city.

It was not until about 1901 that the Meramec project assumed a shape definite enough to attract sufficient attention to warrant a detailed investigation of its merits. It developed that this plan called for an expenditure of more than $30 000 000 and the abandonment of the existing pumping stations. As an alternative it was proposed to build a mechanical filtration plant to cost approximately $2 000 000, with an estimated cost of operation of $7.43 per 1 000 000 gal., amounting to an annual charge of about $200 000. In either case, aside from the expense, it would be a matter of years before the city could expect material improvement in the quality of its water supply.

Under the conditions thus briefly described, the present Water Commissioner assumed office in May, 1903. Work was started at once upon a plan designed for a system of flowing sedimentation, the settlement

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Section through Lime Bin

of size for 1" bar of

top of bolts for gate

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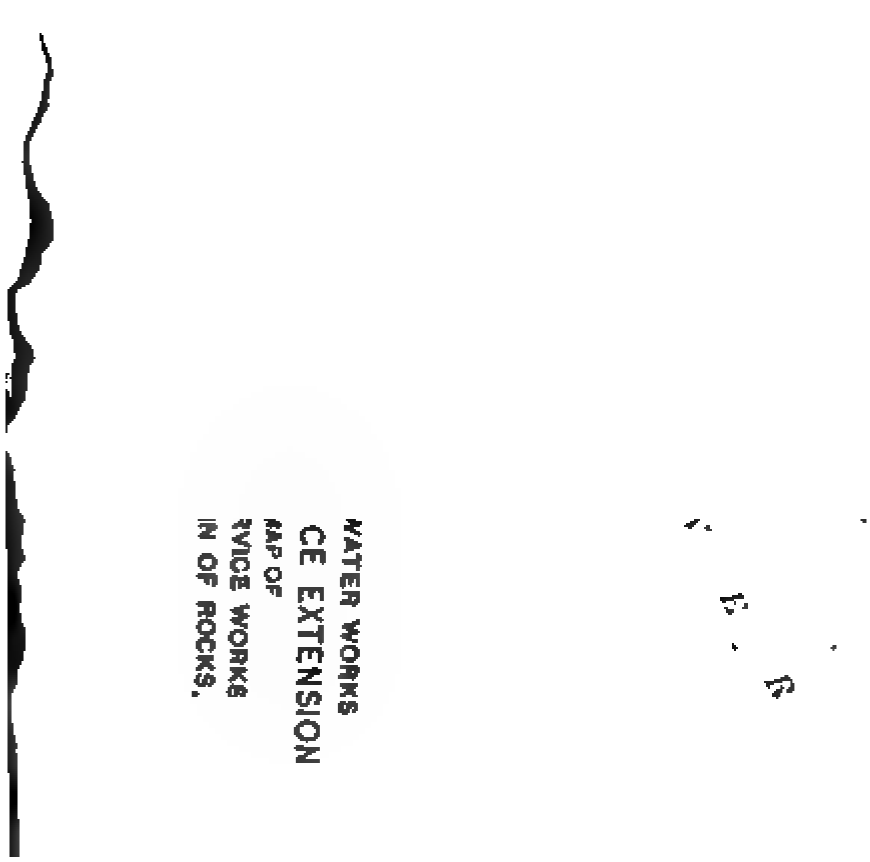

Fig. 1

to be hastened by the use of some coagulant, presumably sulphate of alumina. This plan necessitated the cutting down of the walls separating the basins so as to form a series of weirs over which the water would flow in a thin sheet in passing from basin to basin. The weirs were 610 ft. in length, surfaced with brick, with baffles, for agitating and aerating the water, made by setting one course of brick on end. At the north end of the basins a receiving chamber, 610 ft. long, was built to distribute the water, at its entrance into the system of basins, over a weir, similar to the weirs between basins. This chamber was separated into two longitudinal compartments by a middle wall, perforated at the bottom with numerous openings about 3 in. high by 24 in. long. The water coming into the west end of the northern compartment, filled the southern compartment through the openings at the base of the middle wall and flowed evenly over the weir into the first basin. This chamber was designed with curved sides and bottom so that sediment would not accumulate and stop the passage of water through the small openings. In actual service this chamber admirably fulfilled the purposes for which it was designed, but, for reasons which developed later, its use was discontinued.

The original idea was to use sulphate of alumina as a coagulant, and to introduce it, in the form of a solution, along the weir between the first and second basin, through a submerged pipe lying along the upper side of the weir and discharging through small openings 2 or 3 ft. apart. A similar scheme for introducing a solution of sulphate of alumina into water for the purpose of aiding sedimentation was and had been in use at the Kansas City Water-works for several years.

The problem of removing the sediment from the basins was to be solved by using a floating dredge, designed somewhat after the models of those belonging to the Mississippi River Commission. The dredge had been built and used experimentally in the basins a year or so before this time.

Some time in August, 1903, the attention of the Water Commissioner was called to the use of lime and sulphate of iron as coagulants in conjunction with mechanical filters at Quincy, Ill. All available information on the subject was collected, and in October, 1903, experiments were started in the Laboratory of the Water Department to determine the relative efficiency and cost of the lime and sulphate-of-iron treatment with similar results produced by sulphate of alumina. In

PLATE LXXVII.
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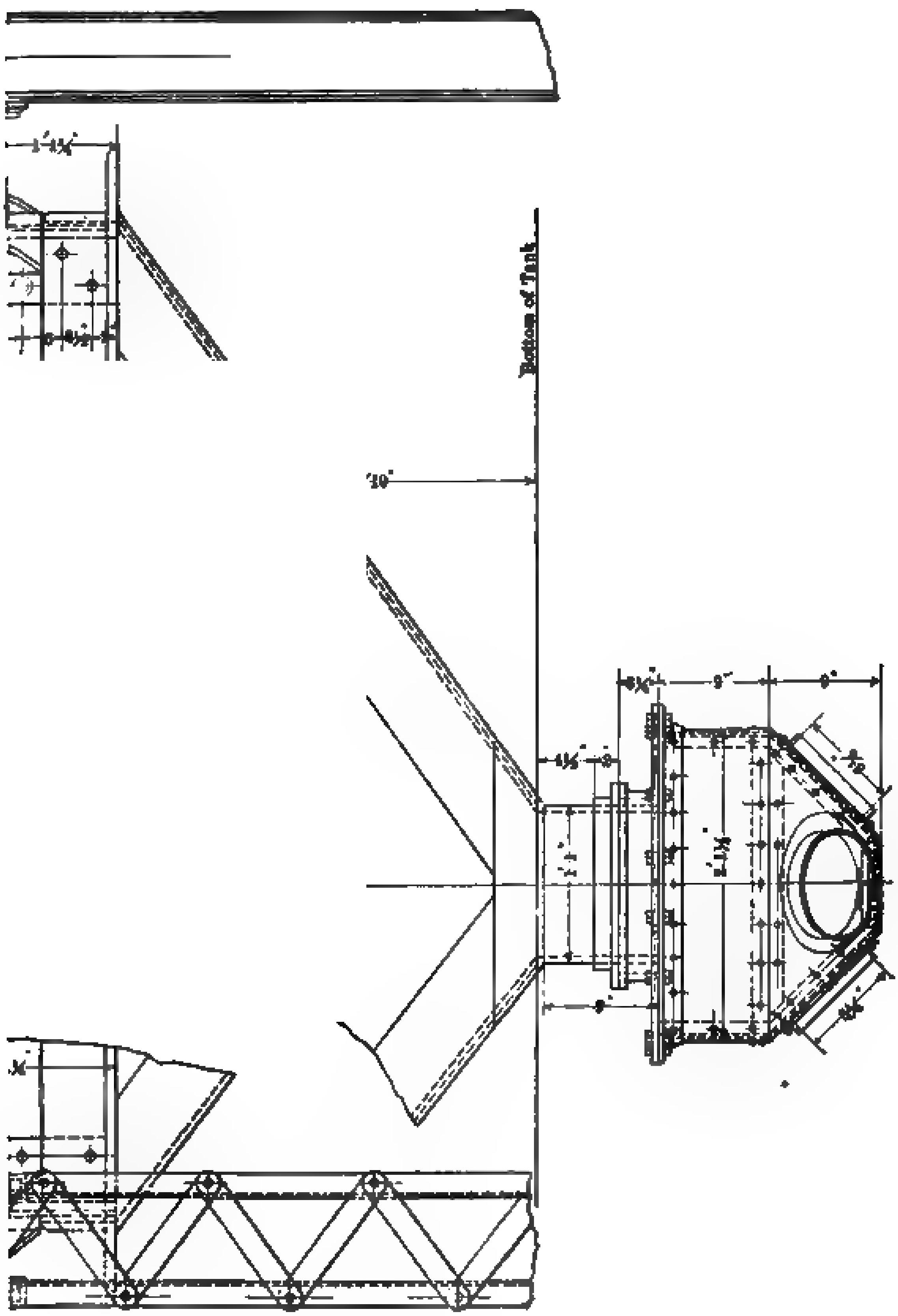


a very short time there seemed to be no question of the superiority of the lime and sulphate-of-iron treatment in cost, efficiency and safety.

In November, 1903, the Water Commissioner and the writer visited the Quincy plant and were shown the practical application of the lime and sulphate-of-iron process in all its details. The action of these coagulants on the raw water on a large scale, was so exactly a reproduction of the Laboratory work, that the conclusion was inevitable that this process, modified to suit St. Louis conditions, would produce a wonderful improvement in the water supply.

Work was immediately begun on designing methods of application, of storing and handling chemicals, of changing projected plans to conform to later ideas, and of abandoning certain work already done. On March 22d, 1904, the plant was put in operation, and St. Louis has had no muddy water since, except on the few occasions when the operation of the plant has been interfered with by breakdown or accident.

The treatment consists in the addition of sulphate of iron and lime to the water in such quantities as are necessary to produce an efficient coagulation and a rapid subsidence of all suspended matter. The amount of sulphate of iron added varies from ½ gr. to 4 gr. per gal. of raw water, and the lime from 5 to 9 gr., depending on the quality of the raw water.

The Mississippi River water holds in solution bi-carbonate of lime and magnesia, free carbonic acid and sulphate of lime, all of which are reduced by the treatment except the sulphate of lime which is slightly increased on account of the action of the lime upon the sulphate of iron as follows:

$$Fe\,SO_4 + 7\,H_2O + CaH_2\,(CO_3)_2 = Fe\,H_2\,(CO_3)_2 + CaSO_4 + 7\,H_2O$$

The action of the lime is then as follows:

$$\begin{aligned} Fe\,H_2\,(CO_3)_2 + 2\,Ca\,(OH)_2 &= Fe\,(OH)_2 + 2\,CaCO_3 + 2\,H_2O \\ CO_2 + Ca\,(OH)_2 &= CaCO_3 + H_2O \\ Ca\,H_2\,(CO_3)_2 + Ca\,(OH)_2 &= 2\,CaCO_3 + 2\,H_2O \\ Mg\,H_2\,(CO_3)_2 + 2\,Ca\,(OH)_2 &= Mg\,(OH)_2\,CaCO_3 + 2\,H_2O \end{aligned}$$

The ferrous hydrate, [Fe $(OH)_2$], remaining in the water oxidizes into ferric hydrate, thus:

$$2\,Fe\,(OH)_2 + H_2O + O = Fe_2\,(OH)_6.$$

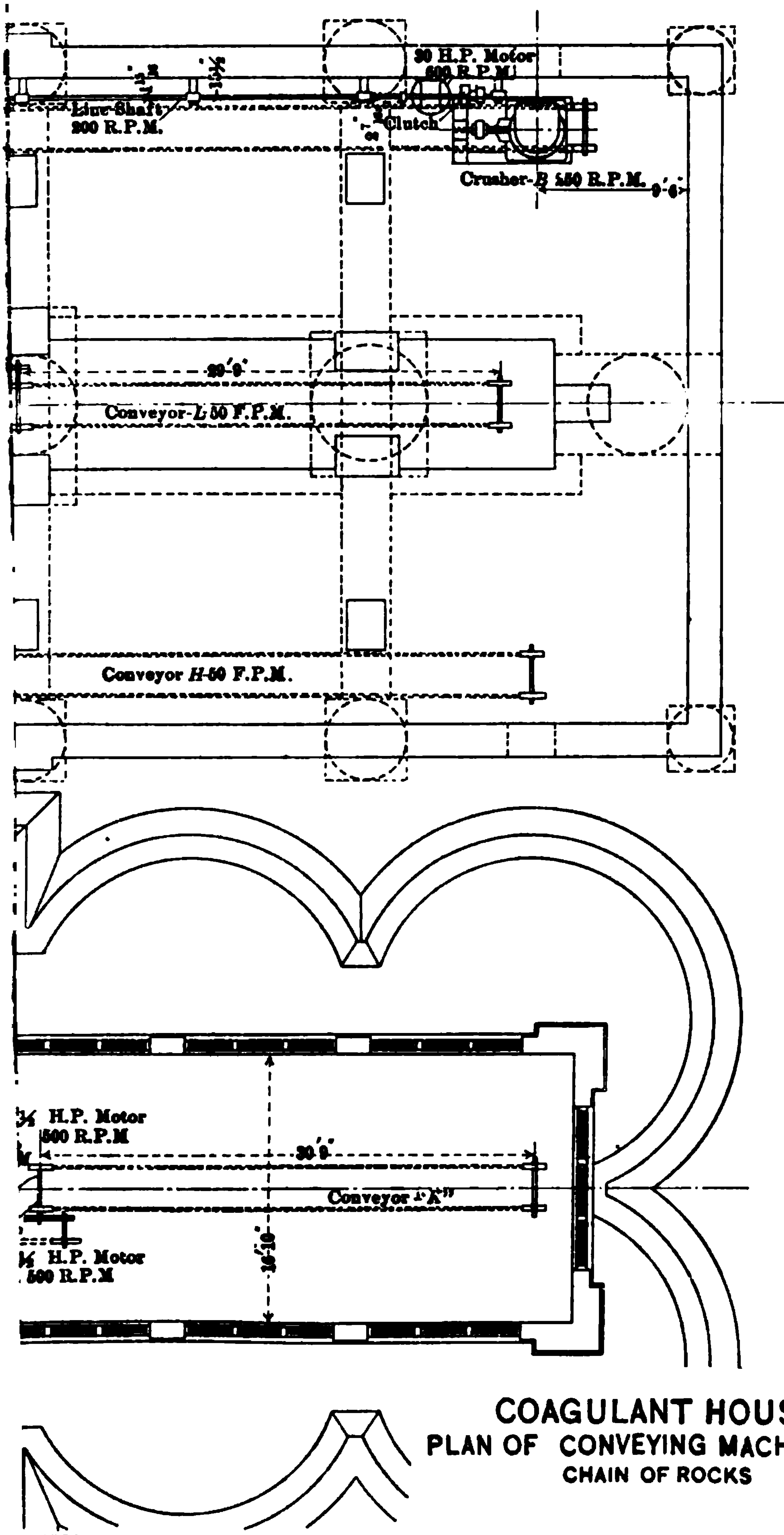
The normal carbonate of lime ($CaCO_3$), is only slightly soluble in water and crystallizes about the particles of suspended matter and on the flocculent precipitate of ferric hydrate, which also entangles portions of the suspended matter and serves to drag down the whole mass of matter in suspension, together with a very large percentage of the bacteria.

The hydrate of magnesia, $Mg\ (OH)_2$, precipitated, will settle out of the water slowly. It is insoluble, but as the water absorbs carbonic acid from the air, it will gradually be converted back into bi-carbonate of magnesia and again be taken into solution.

The original methods of applying the lime and sulphate of iron to the water, which have been considerably modified during the three years' operation, were the result of careful study and observation.

At Quincy, Ill., and at other places, the lime was reduced to a solution of lime-water and added in a constant quantity of known strength. To undertake to add the requisite quantity of lime, in the form of lime-water, to the raw water used in St. Louis, meant the reduction of from 30 to 40 tons of lime daily, which would necessitate a maximum capacity of about 10 000 000 gal. of lime-water. To manufacture such a quantity of lime-water every 24 hours would require an equipment of machinery and storage so large as to make the idea utterly impracticable, besides introducing other complications on account of the variations in strength of the lime-water due to temperature, which would require accurate and frequent determinations and changes in the measured quantities applied to the raw water. After a great many experiments it was decided to apply the lime in the form of milk of lime carrying from 5 000 or 6 000 gr. of lime per gal.

The method of manufacturing the milk of lime was as follows: Circular tanks, 6 ft. in diameter and 3 ft. deep, with revolving rakes to keep the hydrate of lime in suspension, were provided, and found to be capable of slaking 1 800 lb. of lime per hour each, when supplied with about 30 gal. of water per minute at a temperature of 120° fahr. The lime was added in weighed quantities to these tanks at 5-min. intervals, the weights corresponding to the number of gallons pumped per 5 min. multiplied by the number of grains per gallon added. This arrangement gave a continuous flow of milk-of-lime of practically constant strength, so long as the weight of lime added every 5 min. remained constant.



COAGULANT HOUSE
PLAN OF CONVEYING MACHINERY
CHAIN OF ROCKS

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The tanks for dissolving the sulphate of iron were 4 by 5 by 3 ft. deep, supplied with a continuous flow of cold water introduced at the bottom of the tanks through a number of ⅜-in. pipes with perforated caps, giving a network of horizontal streams over the bottom of the tank. The sulphate of iron was dumped into the tanks at 5-min. intervals, in weighed quantities corresponding to the gallons of water being pumped and the grains per gallon added.

The quantities of water supplied to the lime and sulphate-of-iron tanks may vary considerably, provided that so much water is not added as to produce a velocity high enough to carry small particles over in suspension, and also that, in the first case, enough water is supplied to each tank to convert the lime into a milk of lime which will flow readily, and, in the other, to dissolve the sulphate of iron entirely, since the proper weights of lime and sulphate of iron are added at 5-min. intervals.

The solution of iron sulphate is introduced into the water supply through an iron pipe leading down the uptake shaft, where it becomes thoroughly mixed with the river water in its passage to and through the pumps.

The milk of lime flows from the mixing tanks to a collecting tank, where it is diluted and cooled to about 100° fahr., whence it is pumped by a 20-h.p. centrifugal pump to the delivery well which receives the discharge from the low-service pumps. The milk of lime falling into this delivery well is mixed thoroughly with the water discharged from the pumps, which has already been treated with the sulphate of iron. By the time the water reaches the basin, coagulation has taken place, and the settlement begins as soon as the initial velocity of the entering water is sufficiently reduced. Fig. 2, Plate LXXXV, shows within what limited space this occurs.

Probably more than 90% of the suspended matter settles to the bottom of the basin into which the water is first introduced, and the degree of improvement in clarification produced by the journey of the water through the succeeding basins is not so marked, yet there is a vast difference between the quality of the water in the second basin and that in the sixth and last.

A long series of experiments was made in the attempt to determine the velocity of the water through the basins. The velocities are so low and the variations so great, the direction of currents so indeterminate

and so readily influenced by the wind, that it has been impossible to do more than to approximate roughly the velocities along the center line of the basins, the weather conditions being practically the same for all observations.

The following velocities are averaged from a number of observations, rod floats being used, the quantity of water passing through the basin at the time being at the rate of 70 000 000 gal. per 24 hours:

Float	submerged	6 in.,	velocity	5.35	ft.	per	min.
"	"	1 ft.	"	5.60	"	"	"
"	"	2 "	"	5.57	"	"	"
"	"	3 "	"	5.06	"	"	"
"	"	4 "	"	4.86	"	"	"
"	"	5 "	"	3.78	"	"	"
"	"	6 "	"	3.33	"	"	"
"	"	7 "	"	2.92	"	"	"
"	"	8 "	"	2.65	"	"	"
"	"	9 "	"	2.37	"	"	"
"	"	10 "	"	2.35	"	"	"

Floats of various designs were experimented with, for example, spherical surface floats of wood and of copper, double-ball floats, double floats with the upper float hemispherical and the lower one spherical, the two connected in one case by cotton cord, again by thin wire, and again by a small wooden rod, besides other forms and combinations. Fairly uniform results were obtained from the rod floats made of wood, 1⅝ in. in diameter. Observations taken by all other floats were so erratic that no use could be made of them.

Soon after this clarification process was put into operation, it was discovered that the agitation produced by the water flowing over the weirs was interfering with the sedimentation. The interference with the smooth flow of the water tended to break up the coagulated particles and to reduce them to such a state of fineness that sedimentation would not occur much more readily than in the raw water. This caused the abandonment of the use of the entrance chamber at the north end of the basins, and led to the practice of submerging all the weirs, so that the flow from basin to basin was smooth and uninterrupted. The water was introduced into Basin No. 1 through the gate connected with the filling conduit on the west side of that basin. These changes produced

PLATE LXXIX.
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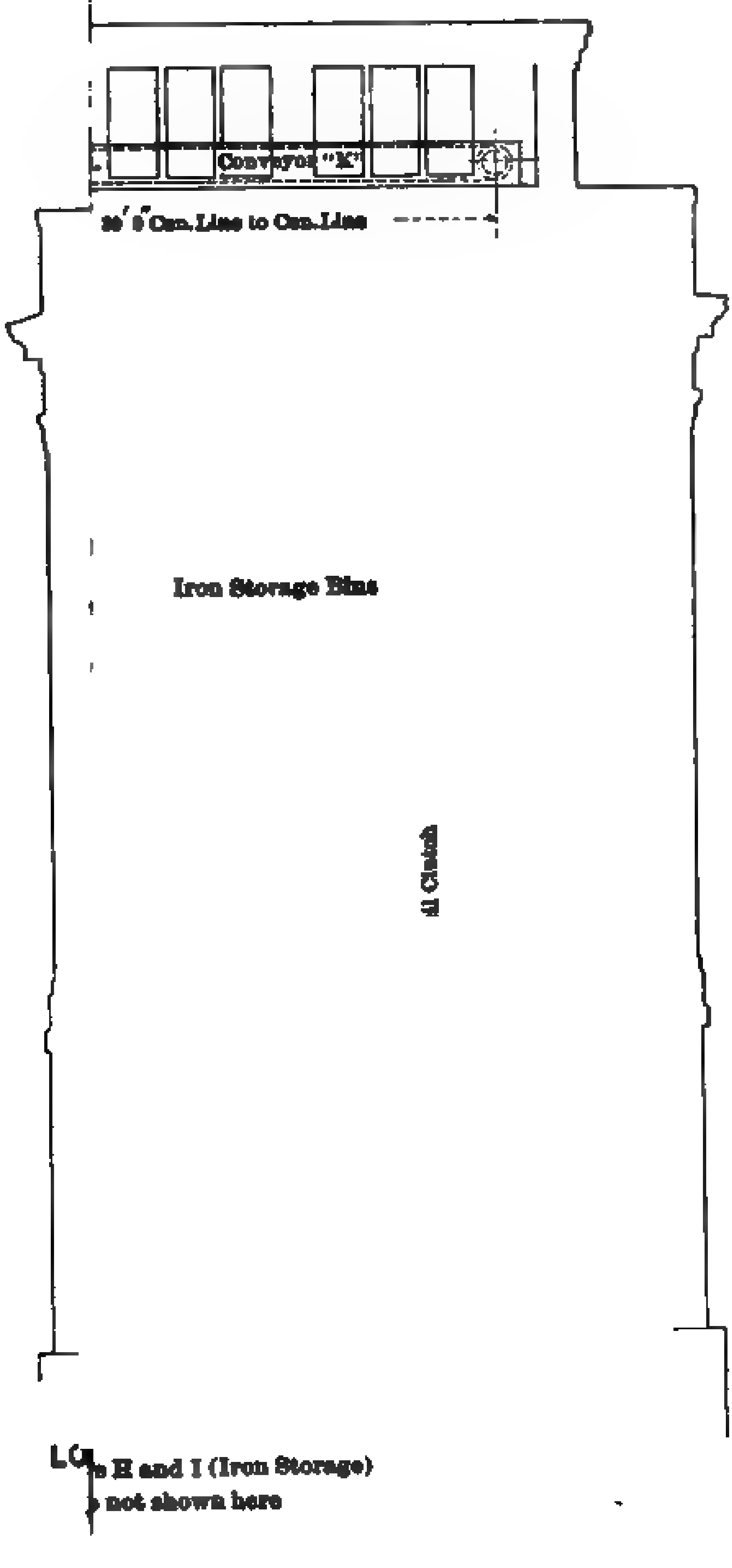
WATER PURIFICATION AT ST. LOUIS, MO.



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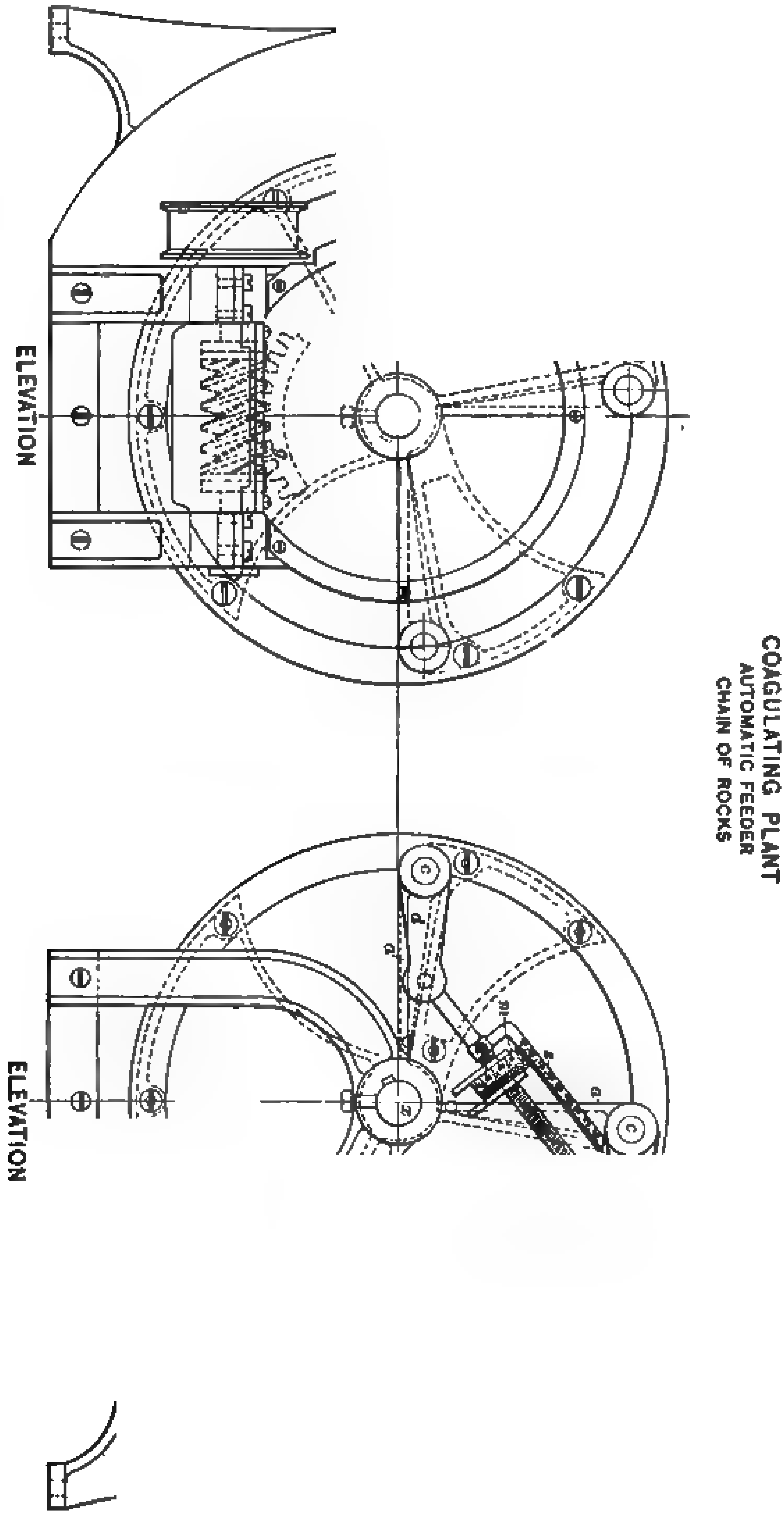
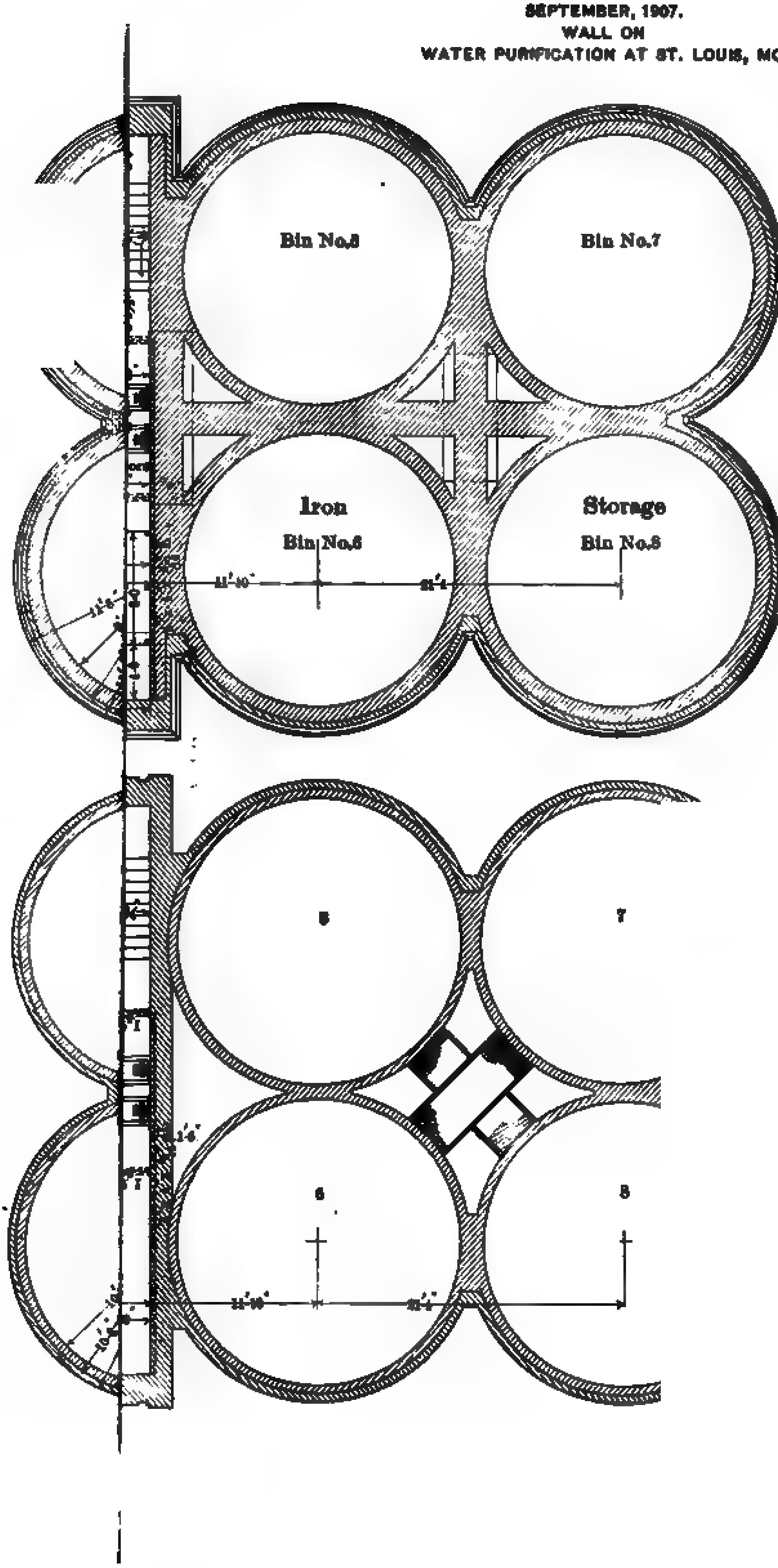

COAGULATING PLANT
AUTOMATIC FEEDER
CHAIN OF ROCKS
ELEVATION
ELEVATION

Fig. 2.

excellent results until the sediment accumulated in Basin No. 1 to such an extent that the inflow of water stirred up the deposited sediment and actually remuddied the clear water. To correct this a baffle was built in front of the inflow pipes of Basins No. 1 and No. 6. This baffle brought all the incoming water to the surface and kept the currents at or near the surface. With this arrangement the basin could be kept in service until the sediment accumulated within a few inches of the top of the baffle. By opening the sewer gate on the east side of the basin, and leaving it open until the effluent became almost clear, a vast quantity of mud was washed out of the basin daily, thus allowing it to be kept in service for much longer periods without being emptied and cleaned. When it finally became necessary to empty and clean Basin No. 1, the water was introduced from the filling conduit into Basin No. 6 through the west gate, reversing the flow through the basin and drawing the clear water from Basin No. 2, while Basin No. 1 was emptied and cleaned. Basin No. 1 was then filled with clear water over the weir from Basin No. 2, and the clear water supply was drawn from Basin No. 1 until Basin No. 6 had to be cleaned, when the flow was again reversed and the operation resumed as in the first case. It soon became apparent that only these two basins would need frequent cleaning under this system of operation, whereas formerly all the basins had to be regularly cleaned, necessitating the constant employment of a force of men in the basins for about seven months of the year. It has developed that these end basins require cleaning after two or three months' service, depending upon the character of the river water. The cost of cleaning is not more than one-third of what it was under the old system, although all the sediment plus the lime and iron sulphate is deposited in the basin now, while 75 or 80% only was deposited there under the old system.

While the practical results obtained by this process of water purification have been very gratifying during the entire time it has been used, it is only within the last year of its operation that the methods, the working, and the results have been subjected to systematic study and analysis. Previous to that time the Department was kept fully occupied in making changes to rectify glaring faults which required neither study nor science to discover, although the remedy was not always so obvious.

Practically all the chemical and bacterial work on the raw and


Bin No.5
Bin No.7
Iron
Storage
Bin No.6
Bin No.8
5
7
6
8

treated water during the first two years of operation was done outside of the Department by the City Chemist and the City Bacteriologist, and under the direction of the Board of Health.

TABLE 1.—AVERAGE PERCENTAGES AND REDUCTION BY MONTHS.

Date.	Suspended Solids. P. P. M.		Dissolved Solids. P. P. M.		Bacteria, per Cubic Centimeter.		
	River.	Tap.	River.	Tap.	River.	Tap.	% Removal.
April, 1904	2 400	130	189	160	196 500	22 940	86.0
May, 1904	1 548	65	206	161	57 000	5 850	93.0
June, 1904	3 372	39	206	165	27 000	1 050	96.0
July, 1904	2 488	48	212	144	26 000	323	98.7
August, 1904	1 290	40	257	170	15 180	817	95.0
September, 1904	1 000	15	228	177	14 200	225	98.2
October, 1904	460	13	301	194	....	....	....
November, 1904	228	9	320	195	24 300	4 050	82.5
December, 1904	256	9	352	227	48 250	4 587	90.5
January, 1905	79	16	414	242	20 000	1 857	90.7
February, 1905	29	4	406	230	39 350	1 341	96.5
March, 1905	942	9	225	180	33 700	1 910	94.4
April, 1905	440	6	206	156	66 080	2 200	96.8
May, 1905	965	30	278	234	15 130	900	94.0
June, 1905	1 040	15	231	158	32 310	619	98.4
July, 1905	2 606	41	233	183	91 000	1 750	98.2
August, 1905	1 746	24	216	165	40 400	400	99.0
September, 1905	1 125	16	218	185	32 400	350	98.9
October, 1905	730	15	224	156	53 820	390	99.3
November, 1905	395	10	248	155	46 250	1 863	96.0
December, 1905	338	10	316	186	48 520	848	98.4
January, 1906	496	7	231	151	144 420	1 810	98.7
February, 1906	259	0	247	144	47 220	1 164	97.5
March, 1906	858	3	166	118	66 560	202	99.7

Special tests, taking daily samples for from 10 days to 2 weeks, for the purpose of determining the presence of *B. Coli Communis* have been made at various times and by different observers. Except in one or two doubtful cases the total absence of *B. Coli* in the tap water was established beyond any reasonable doubt.

Table 2 shows the improvement in the purity of the water supply in a marked degree.

The population of St. Louis, in 1900, was 575 000, in round numbers; in 1907, it is 700 000. The record for 1904 must be read, bearing in mind that the purification process was not started until April and that 1904 was the year of the World's Fair in St. Louis, which temporarily increased the population by many thousands, and, under the conditions prevailing in previous years, an increase in the number of cases and deaths from all diseases could reasonably have been expected.

TABLE 2.—CASES AND DEATHS FROM TYPHOID FEVER IN ST. LOUIS, SINCE JANUARY 1ST, 1900.

	1900.		1901.		1902.		1903.			1906.		1907.	
Months.	C.	D.	C.	D.	C.	D.	C.	D.	C	.	D.	C.	D
January	57	19	78	8	108	14	81	18		33	7	12	5
February	42	5	55	14	59	16	55	15		17	5	15	6
March	117	16	82	11	34	11	91	20		18	6	14	9
April	34	4	94	4	48	14	79	17		17	5	....	....
May	29	4	22	8	38	11	86	15		12	3	....	....
June	26	8	26	6	28	7	90	16		14	3	....	....
July	43	16	49	18	33	14	189	26		50	8	....	....
August	119	20	185	31	58	26	251	37	1	54	16	....	....
September	258	18	189	24	169	21	201	49	1	85	29	....	....
October	262	30	206	33	194	32	188	30		01	14	....	....
November	197	15	154	27	169	31	131	23		50	11	....	...
December	104	19	125	20	106	25	119	31		94	5	....	...
Totals	1 218	168	1 101	198	1 112	222	1 586	297	6	10	112	....	....

The typhoid rate was 29.4 per 100 000 in 1900, increasing to more than 40 per 100 000 in 1903, and then decreasing to 16 per 100 000 in 1906. This, in itself, does not express the total beneficial effect on the general health arising from the use of pure water. Allen Hazen, M. Am. Soc. C. E., estimates that where one death from typhoid has been avoided through an improved water supply, probably two or three deaths from other diseases have been avoided. The following record seems to indicate a higher proportion of decrease than Mr. Hazen's estimate would give:

ANNUAL MORTALITY RECORD, ST. LOUIS, MO., 1900 TO 1906, FROM DISEASE ALONE:

1900	9 217	1904	10 695
1901	9 916	1905	9 545
1902	9 654	1906	9 214
1903	10 320		

The original method of preparing both the iron solution and the milk of lime was not entirely satisfactory from the first. The iron solution, as it came from the tank, varied in strength at times as much as 25% from the normal, due to adding the charges at 5-min. intervals while the stream of water flowing through the mass was constant. Evidently as the mass dissolved toward the end of the 5-min. period, less

sulphate of iron would be exposed to the water, and the solution would be weaker. The extent of variation could be limited by reducing the water supply to the minimum quantity necessary to keep the sulphate dissolved approximately as fast as added, but a simpler and more certain way of maintaining a constant strength solution would be by feeding the sulphate to the tank continuously and evenly. The sulphate of iron is shipped in bulk and is known as "sugar" sulphate. It is similar in fineness to granulated sugar, and when perfectly dry will flow like dry sand. The physical condition of the sulphate is not uniform enough to allow of the use of a standardized orifice, so that it became necessary to design an apparatus for automatic force feeding, which would ensure the measurement of equal volumes, in equal times, and be susceptible of adjustment to various rates of feeding. The range of the apparatus must cover all rates from 2½ to 50 lb. per min.

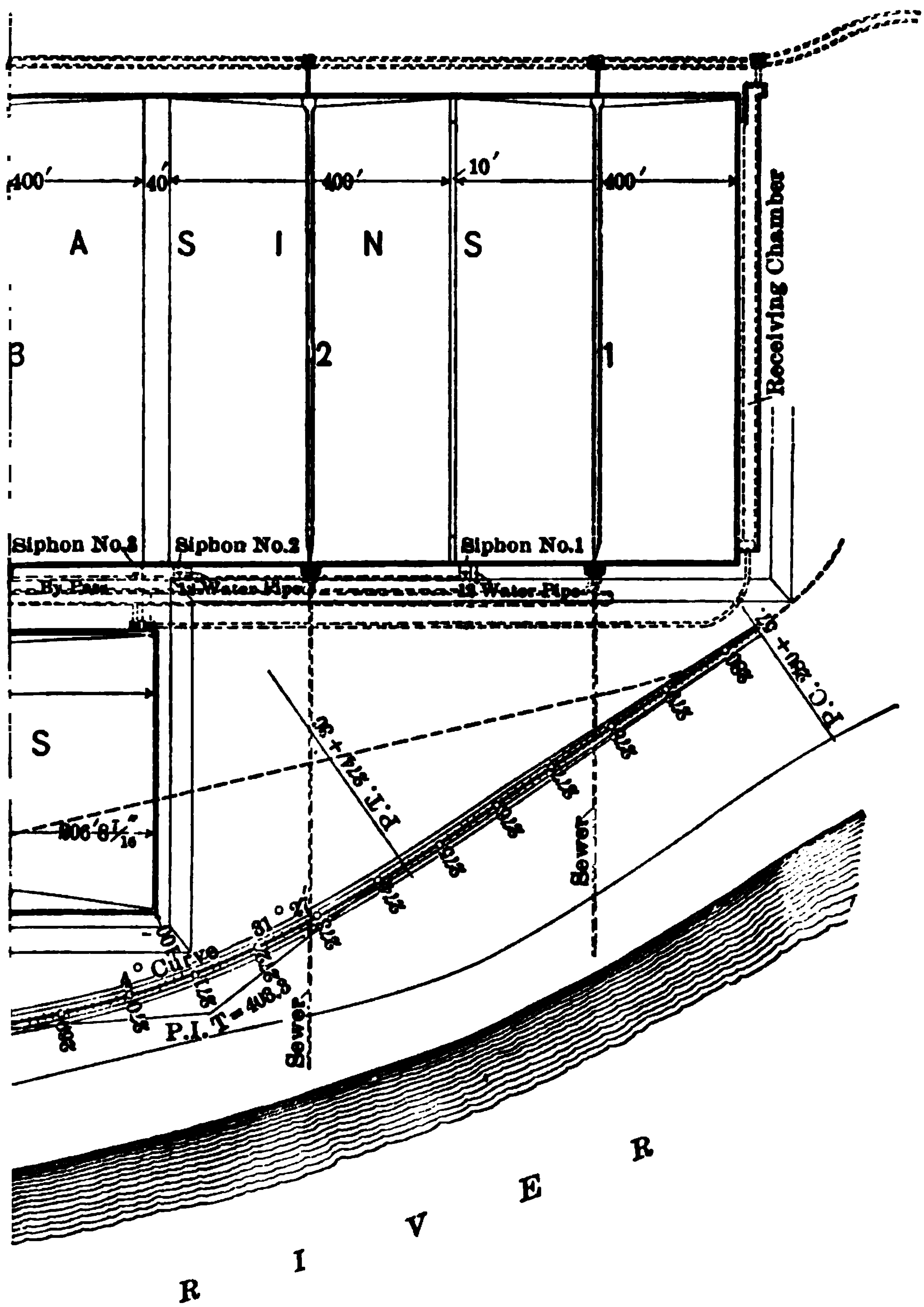
The machine shown on Fig. 2 was designed and built in the Department, and when operated its measurements were found to be absolutely uniform. The machine consists of a cylinder about 12 in. in diameter and 5 in. long, with two pockets whose size may be varied by the movement of the side, *a*, which revolves about *C* as a center. This adjustable side fits closely to the ends of the cylinder and to the curved side of the pocket. These adjustable sides are moved by the arms, *d, d,* which, in their turn, are moved by the micrometer screw, *m,* while the positions of the movable sides are shown by the scale, *s*. The cylinder revolves on the axis, *x,* and is driven by the worm gearing, *g*. The cylinder is partially covered by a casing which serves to hold the full load in the pockets until they reach the position for dumping, and also to prevent the escape of material from the hopper. The cylinder revolves at a constant speed, about 12 rev. per min., and measures and discharges a constant volume of material in equal periods of time.

Tests made to determine the available amount of calcium hydrate carried by the milk of lime, as manufactured by the system of tanks described heretofore, showed that there occurred a heavy loss, amounting at times to as much as 35% of the theoretical value of the quicklime weighed into the tanks. About 3% of this loss is due to impurities in the quicklime, such as sand, dirt, flint and underburned stone. Another portion of loss is due to the air-slaking of the quicklime

in transit and in storage. In very warm, moist weather this loss is considerable, but during the greater part of the year it is very small. The greatest part of the loss was found to be due to imperfect hydration, small particles of unslaked lime being carried out of the tanks in suspension. Lowering the velocity through the tanks by reducing the quantity of water, at 120° fahr., supplied to them, increased the efficiency and raised the temperature of the tank contents. Increasing the temperature of the water supplied to the tanks from 120° to 150° fahr., without cutting down the quantity, resulted in an increased efficiency of about 15% and raised the temperature in the tanks to almost 200° fahr.

By supplying the tanks with a quantity of water (at 50° fahr.) approximately equal by weight to three times the weight of quicklime added, complete hydration resulted with a tank temperature of more than 200° fahr. This was unsatisfactory because the tank contents became too thick to flow readily through the outlet pipe, and, if not constantly watched, would eventually become so stiff as to stop the stirring apparatus. An addition of too much cold water would reduce the temperature of the tank contents too low for efficient hydration. This led to the idea of utilizing the heat of the effluent from the tanks for heating the water supply. This was accomplished by the addition of an auxiliary tank into which the milk of lime is conducted from the several slaking tanks. This auxiliary tank contains a coil through which the cold water flows on its way to a head tank, from which the supply is piped to the slaking tanks. The head tank is equipped with a float valve to regulate the flow of incoming water, so that a constant head is kept on all the feed pipes leading to the slaking tanks. Each feed pipe has, at its lower end, an adjustable orifice to regulate the quantity of water supplied to each tank, so that the quantity of water entering each tank is from 3¼ to 3¾ times as much by weight as the lime added to that tank. The temperature of the tank contents is over 200° fahr., and that of the water in the head tank about 100° fahr., varying with the temperature and quantity of the cold water entering the coils. This arrangement has been in service for several months and has shown a decided reduction in the expense of operation.

The total quantities of sulphate of iron and lime used during the first year of operation were: 3 578 tons of sulphate of iron, and 14 291 tons of lime; during the second year: 4 138 tons of sulphate of iron,



LOW SERVICE EXTENSION
BASINS 7 AND 8
LOCATION PLAN

and 11 814 tons of lime; during the third year: 4 050 tons of sulphate of iron, and 14 081 tons of lime.

The total quantity of water treated during the first year was 33 133 million gal.; during the second year, 26 334 million gal.; and during the third year 26 682 million gal.

The average daily consumption of water has not increased proportionately with the population since the clarification of the water supply.

The population of the city has increased from 575 000 in 1900 to 700 000 in 1907. The average daily water consumption for each year during this period follows:

1900-01	63 000 000 gal.
1901-02	67 173 000 "
1902-03	66 211 000 "
1903-04	69 916 000 "
1904-05	79 052 000 "
1905-06	69 000 000 "
1906-07	70 109 000 "

The average quantities of sulphate of iron and lime used during the first year were 1.5 gr. of sulphate of iron and 6.0 gr. of lime per gallon of water treated; during the second year, 2.2 gr. of sulphate of iron and 6.28 gr. of lime; during the third year, 2.13 gr. of sulphate of iron and 7.39 gr. of lime.

The average cost per 1 000 000 gal. of water treated (including labor and power) for the first year was $3.60, for the second year, $3.99 and for the third year, $4.62. The cost in detail is as follows:

	1904-05	1905-06	1906-07
Cost of lime	$1.89	$1.74	$2.45
Cost of sulphate of iron	1.07	1.53	1.44
Labor	0.57	0.62	0.58
Power	0.07	0.09	0.07
Repairs	....	0.01	0.08
	$3.60	$3.99	$4.62

The gradual increase in the cost of purification is due to several causes. During the first year we were proceeding cautiously and often

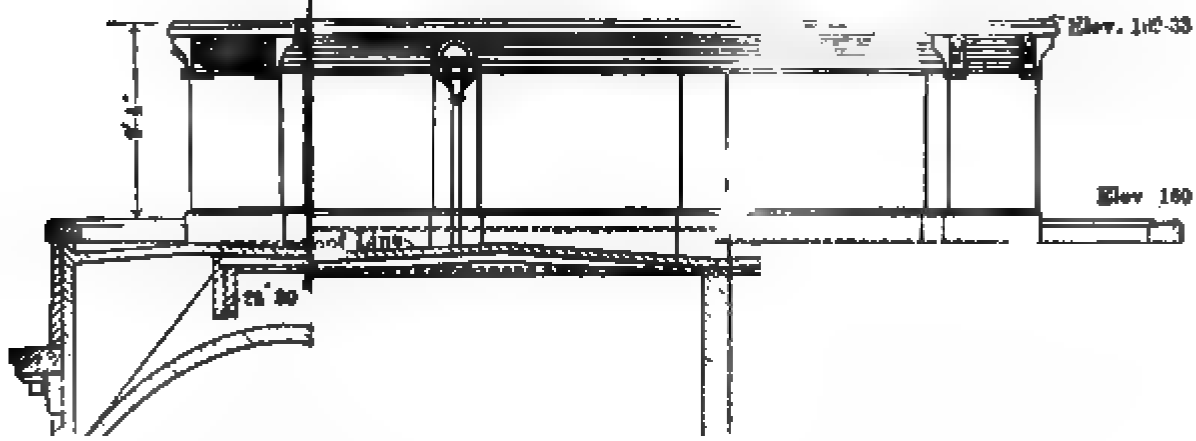
used quantities (both of sulphate of iron and of lime) too small to produce efficient coagulation and settlement. The water as drawn from the settling basins was often turbid and nearly always cloudy. It was not until the latter part of the first year that the efficiency of the treatment began to approach the results which were obtained during the third year. We were also afraid of having caustic lime in the effluent, and, at that time, had not devised any definite method of determining the quantity of lime which it would be safe to add, and in trying to avoid the error of using too great a quantity, we naturally fell into the mistake of adding too little. The increase in cost per 1 000 000 gal. during the third year was due principally to the fact that the price of lime was raised from $3.88 to $4.65 per ton. The average quantity of lime added, in grains per gallon, was greater during the third year on account of the longer period of very turbid water in the river, and because of greater accuracy in proportioning the proper quantity of lime necessary each day and a consequent production of a continuous supply of pure and clear water.

Tables 3 and 4 give comparative analyses of the river and treated water, showing the reduction of bacteria and tests for *B. Coli Communis*. The bacterial tests were not started until November, 1906, on account of delay in equipping the laboratory with the necessary apparatus.

The maximum quantity of sulphate of iron added to the water on any occasion during the third year was 3.75 gr., the minimum being 1.25 gr. per gal. of water treated; of lime, the maximum was 11 gr., and the minimum, 3 gr. per gal. of water treated. These figures are calculated on the weights of sulphate of iron and lime as taken from the bins, but, in the case of the lime, the actual efficient quantity is much less than the record shows, on account of deterioration in transit and in storage from air-slaking; for example, in the case of the 11 gr. mentioned, the actual amount of efficient lime, as determined by analysis, was 7.7 gr. This explains why the average for the year in grains per gallon is as high as 7.39; the average of efficient lime added would be considerably lower. The sulphate of iron does not deteriorate appreciably in storage.

The alkalinity of the treated water during the third year varied from 35 to 75 parts per million, the average being 49. The increase of incrustants through the action of the sulphate of iron averaged 13

PLATE LXXXIII.
PAPERS, AM. SOC. C. E.
SEPTEMBER, 1907.
WALL ON
WATER PURIFICATION AT ST. LOUIS, MO.



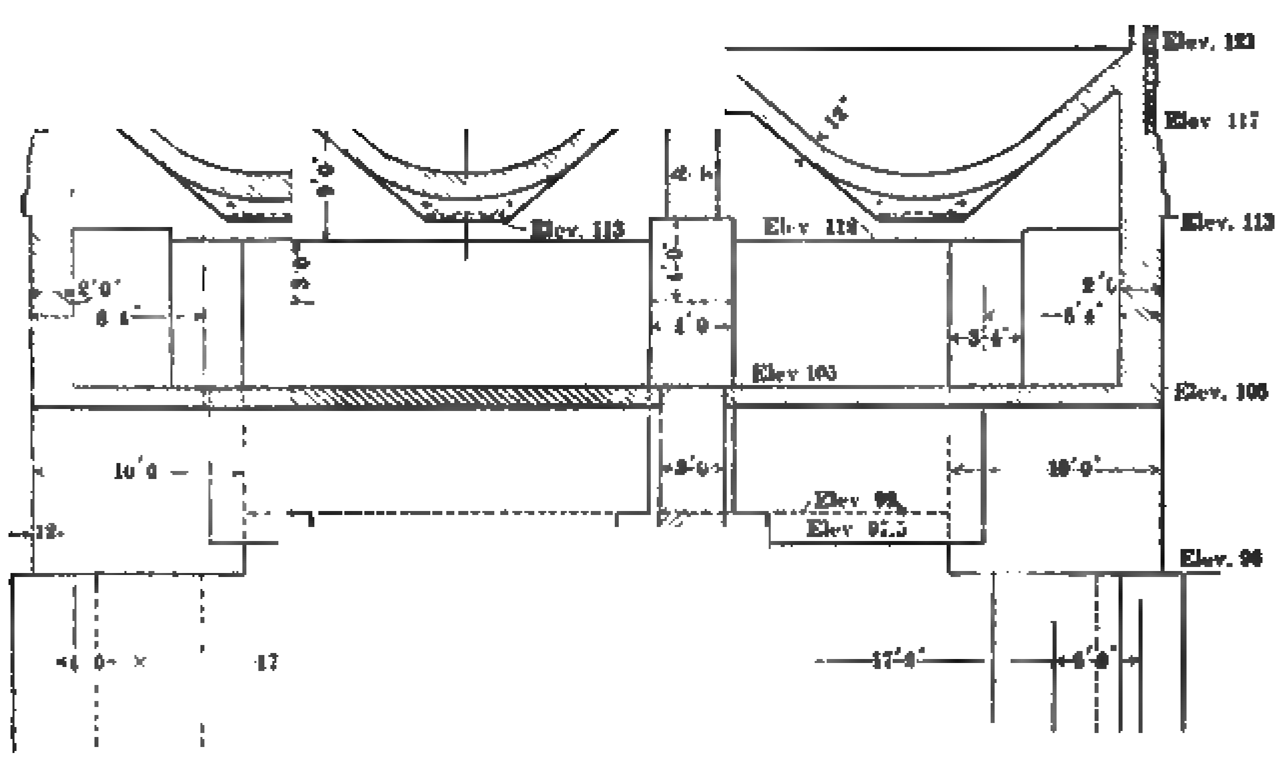


TABLE 3.—ANALYSES OF RIVER WATER, ST. LOUIS, MO.

Date.		Turbidity.	Color.	Suspended Solids.	Dissolved Solids.	Calcium Ions.	Magnesium Ions.	Sulphate Ions.	Alkalinity.	Incrustants.	Neutral Carbonates.	CO_2	Bacteria, per cubic centimeter.
1906.													
Apr.	6..	1 650	45	......	......	33	13	19	90	22	......	1	......
"	13..	1 000	50	......	......	36	10	13	106	......	......	2	......
"	20..	1 800	51	1 116	210	35	12.6	30	120	22	......	3	......
"	27..	500	45	319	180	30	9.5	30	112	......	......	2	......
May	4..	180	51	108	180	32	8.3	35.3	98	17	......	1	......
"	11..	1 900	35	571	226	41	10.4	33	128	22	......	2	......
"	18..	800	35	1 008	246	50	12	41	149	36	......	2	......
"	25..	800	31	711	230	45	15	53	148	28	......	1	......
June	1..	1 050	35	849	231	45	11.1	44	140	30	......	1	......
"	8..	2 400	31	2 030	264	45	11.5	74	134	28	......	3	......
"	15..	3 000	31	3 910	268	43	11.5	74	137	16	......	3	......
"	22..	3 600	35	5 030	273	41	10.8	60	138	15	......	2	......
"	29..	3 800	31	4 230	291	44	13.4	50	134	22	......	4	......
July	6..	3 000	35	3 409	268	......	......	......	128	......	......	3	......
"	13..	2 400	41	2 054	244	......	......	......	118	......	......	2	......
"	20..	1 800	35	1 078	246	......	......	......	120	......	......	2	......
"	27..	1 500	41	1 498	218	35	13	76	128	20	......	1	......
Aug.	3..	1 500	31	1 267	272	44	13	80	129	24	13	....	......
"	10..	1 350	35	956	228	......	......	......	130	......	......	....	......
"	17..	1 600	35	1 225	218	......	......	......	120	......	......	....	......
"	31..	1 800	35	1 654	218	......	......	......	120	......	3	....	......
Sept.	7..	1 350	40	850	242	42	12	55	134	30	10	....	......
"	14..	900	35	720	223	......	......	......	137	......	6	....	......
"	21..	900	35	697	240	......	......	......	148	......	14	....	......
"	28..	2 400	35	1 307	225	......	......	......	135	......	......	1	......
Oct.	5..	1 050	41	840	201	27	12.5	47	119	25	......	2	......
"	12..	900	35	750	248	45	13.6	56	141	20	......	1	......
"	19..	900	35	670	238	......	......	......	152	......	......	2	......
"	26..	550	35	419	214	......	......	......	165	......	8	....	......
Nov.	2..	700	35	771	218	55	16.6	71	174	26	14	....	28 900
"	9..	900	41	556	294	54	17	60	166	40	8	....	35 400
"	16..	750	59	497	238	......	......	......	156	......	10	....	42 000
"	23..	600	68	444	224	......	......	......	156	......	12	....	32 300
"	30..	400	71	371	230	......	......	......	165	......	12	....	20 700
Dec.	7..	450	65	368	230	48	17.8	42	165	23	12	....	......
"	14..	300	45	231	304	50	16.8	48	170	26	10	....	......
1907.													
Jan.	11..	450	35	354	206	53	14.6	48	164	36	......	....	25 900
"	18..	600	60	1 259	210	34	15.8	36	120	31	......	2	30 400
"	25..	1 900	45	1 817	188	......	......	......	67	......	6	....	37 600
Feb.	1..	500	55	630	169	24	9.7	25	90	10	0	2	46 600
"	8..	250	70	219	230	33	16	42	135	11	6	4	25 600
"	15..	900	35	336	246	......	......	......	168	......	......	3	18 200
"	21..	800	35	492	230	......	......	......	158	......	......	3	......
Mar.	1..	1 800	45	1 700	230	42	11	62	140	10	......	5	65 800
"	8..	900	45	1 069	245	40	15	48	133	31	......	4	48 700
"	15..	1 500	70	2 005	216	34	12	51	110	24	......	2	88 200
"	22..	1 500	50	1 905	275	......	......	......	146	......	......	3	36 100
"	29..	1 900	30	1 190	267	......	......	......	142	......	......	2	12 900

TABLE 4.—Water Analyses, Clear Well at Bissell's Point.

Date.	Color.	Suspended Solids.	Dissolved Solids.	Calcium Ions.	Magnesium Ions.	Sulphate Ions.	Alkalinity.	Incrustants.	Caustic Alkalinity.	Bacteria, per cubic centimeter.	Removal, per cent.
1906.											
April 6	20	......	......	25	5.8	22	37	48	5	......	......
" 13	10	......	......	24	3.6	55	37	37	3	......	......
" 20	12	3.6	150	20	2.9	55	40	21	0	......	......
" 27	12	5.2	146	28	4.1	46	42	45	6	......	......
May 4	10	10.0	110	22	5.0	32	46	29	7	......	......
" 11	12	27.2	151	24	3.8	69	40	36	6	......	......
" 18	12	10.0	155	25	4.3	60	43	37	1	......	......
" 25	14	7.6	190	21	6.4	64	44	40	0	......	......
June 1	10	0.0	160	22	5.0	44	39	36	1	......	......
" 8	12	5.6	184	26	3.8	37	39	42	3	......	......
" 15	12	5.2	201	31	2.3	33	40	46	6	......	......
" 22	10	4.4	203	36	1.7	33	45	52	15	......	......
" 29	10	6.0	246	41	1.2	90	52	54	20	......	......
July 6	10	5.8	263	......	......	......	51	......	15	......	......
" 13	10	6.4	215	......	......	......	53	......	15	......	......
" 20	10	4.4	212	......	......	......	55	......	21	......	......
" 27	12	5.6	187	25	4.8	80	47	34	3	......	......
Aug. 3	12	2.4	192	23	6.0	87	48	35	0	......	......
" 10	10	0.0	180	......	......	......	41	......	0	......	......
" 17	10	2.4	160	......	......	......	......	......	0	......	......
" 31	10	7.6	147	......	......	......	45	......	1	......	......
Sept. 7	10	3.6	159	18	4.8	66	46	19	0	......	......
" 14	10	1.2	168	......	......	......	47	......	5	......	......
" 21	10	1.6	169	......	......	......	50	......	2	......	......
" 28	12	3.6	171	......	......	......	50	......	0	......	......
Oct. 5	15	3.6	155	25	5.8	56	52	34	4	......	......
" 12	10	3.6	170	22	7.2	80	53	32	0	......	......
" 19	10	3.2	182	......	......	......	59	......	0	......	......
" 26	10	4.0	194	......	......	......	57	......	1	......	......
Nov. 2	10	2.8	206	21	12.5	77	59	45	0	2 600	90.0
" 9	12	1.6	209	21	11.8	71	56	46	2	2 000	94.8
" 16	10	3.2	196	......	......	......	55	......	0	5 000	85.7
" 23	10	0.4	196	......	......	......	58	......	0	600	98.1
" 30	10	4.0	197	......	......	......	60	......	2	1 200	94.2
Dec. 7	8	5.6	192	21	14.5	58	60	52	0	......	......
" 14	10	4.4	186	20	13.0	48	58	47	0	......	......
" 21	8	3.2	194	......	......	......	62	......	0	......	......
" 28	8	0.0	210	......	......	......	68	......	0	......	......
1907.											
Jan. 4	8	0.0	292	......	......	......	75	......	0	......	......
" 11	8	6.0	198	21	12.5	56	64	39	0	330	98.7
" 18	8	1.2	191	22	15.0	48	56	60	0	935	95.4
" 25	12	0.0	135	......	......	......	51	......	17	20	99.9
Feb. 1	12	8.4	180	22	7.9	33	48	37	0	1 200	97.4
" 8	12	1.2	138	21	10.0	55	52	34	0	160	99.4
" 15	12	1.6	148	......	......	......	56	......	0	......	......
" 21	10	0.8	181	......	......	......	61	......	0	......	......
Mar. 1	10	2.0	179	21	10.0	73	51	45	11	00	100.0
" 8	12	4.8	171	19	11.0	64	43	59	0	30	99.9
" 15	12	4.8	165	20	11.0	66	41	56	0	40	99.9
" 22	10	0.4	175	......	......	......	39	......	1	50	99.8
" 29	10	0.0	181	......	......	......	43	......	0	40	99.7

FIG. 1.—RECEIVING CHAMBER, NORTH SIDE OF BASIN NO. 1, AS ORIGINALLY BUILT.

FIG. 2. RECEIVING CHAMBER REMODELED TO INTRODUCE WATER INTO BASIN NO. 1 THROUGH FOUR 3 BY 3-FT. GATES.

parts per million, calculated as calcium carbonate. The softening actually accomplished by the treatment is a reduction of the lime carbonate to 53% of that in the raw water, and of the magnesia to 57%; the average of 204 determinations each, of the amounts of calcium and magnesium in the raw water, were 42.3 and 13.1 parts per million, respectively; in the treated water, 22.8 and 7.54 parts per million.

TABLE 5.—PERCENTAGE OF REDUCTION IN BACTERIA AS THE WATER PASSES THROUGH THE BASINS:

	Basin No. 1.	Basin No. 2.	Basin No 3.
October, 1906	76.4%	82.8%	....
November, 1906	89.0%	90.0%	90.1%
December, 1906	72.2%	77.5%	67.8%
January, 1907	93.7%	96.0%	97.4%
February, 1907	96.0%	98.4%	99.0%
March, 1907	96.1%	99.1%	99.8%

During each day as often as conditions require, samples are taken from each basin, and the caustic alkalinity of each sample determined by titration. Throughout the basins the caustic alkalinity is kept as low as is consistent with efficient coagulation, the aim being to keep down the charge of lime until the last basin shall show little or no caustic alkalinity. It is not possible to maintain any uniform set of conditions throughout the basins on account of the great and sudden fluctuations in the quality of the river water. The quantity of lime added being controlled in this way, the changes in the amount of sulphate of iron necessary are determined from the appearance of the coagulation and from the condition of the water in each basin, turbidity determinations being made from a portion of the samples taken for testing the caustic alkalinity.

Determinations of the turbidity, color, etc., of the raw water and of the water in the basins are carried on daily, a record being kept as shown in Table 6.

The coagulating plant which has been in use for more than three years was originally built as a temporary affair, with the expectation that it would be replaced by a permanent structure after the World's Fair in 1904. The cost of this temporary coagulant plant, with all machinery and connections, was less than $10 000. The cost of changing the settling basins, necessary to put in operation the purification scheme, amounted to about $25 000.

TABLE 6.—LABORATORY RECORD, CHAIN OF ROCKS, ST. LOUIS, MO.

1907.		River Water.						Grains, per Gallon.		Entrance.		Basin No. 1.		Basin No. 2.		Basin No. 3.		Basin No. 4.		Bas'n No. 5.		Basin No. 6.		Wind.	
April.																									
Day.	Hour.	Stage.	Temperature.	Turbidity.	Color.	CO_2	Alkalinity	Lime.	Iron.	Color.	Caustic.	Color.	Caustic.	Color.	Caustic.	Color.	Caustic.	Color.	Caustic.	Color.	Caustic.	Color.	Caustic.	Direction.	
1	8 A. M.	88.9	55°	1 200	35	8	132	6.5	2.25	14	8	14	7	12	8	12	5	12	2	12	8	10	4	N. E.	Mild.
	9 "							6.0	2.0																
	10:30 "							6.0	2.0	14	2	14	4	12	5										
	1 P. M.							6.0	2.0	14	1	14	2	12	4										
	3:30 "							6.0	2.0	16	2	14	2	14	1										
2	8 A. M.	89.2	54°	1 500	45	8	132	6.25	2.25	16	4	14	0	14	—1	14	—1	12	1	12	1	12	1	S.	Brisk.
	9 "							6.75	2.25																
3	8 "	89.2	55°	1 500	45	8	128	6.75	2.25	14	4	14	4	12	5	12	4	12	2	12	1	10	1	S.	Brisk.
	10 "							6.75	2.25																
	3:30 P. M.							6.75	2.25	14	7	14	6	12	4										
4	8 A. M.	89.0	56°	1 500	35	8	123	6.75	2.25	14	6	14	6	12	7	12	6	12	6	12	5	10	5	W.	Mild.
	3 P. M.							6.25	2.0	14	1	12	7	12	9										
5	8 A. M.	88.9	6°	1 350	35	8	126	6.25	2.0	14	11	14	6	12	9	12	6	12	5	10	1	10	4	N.	Brisk.
	9 "							6.0	2.0																
	10:30 "							6.0	2.0	14	8	12	9	12	9										
	3 P. M.							6.0	2.0	14	8	12	6	12	6										
6	8 A. M.	88.9	54°	1 350	35	8	128	6.0	2.0	14	5	14	8	14	8	12	6	12	5	12	5	10	4	E.	Brisk.
	9 "							5.75	2.0																
	10:30 "							5.75	2.0	14	3	14	5	12	8										
	11:30 "							6.0	2.0																
	1 P. M.							6.0	2.0	14	5	14	2	12	5										
7	8 A. M.	88.9	54°	1 500	35	8	130	6.0	2.0	16	8	14	8	14	8	14	6	12	0	12	6	10	6	S. W.	Brisk.
	9:30 "							6.0	2.25																
	1 P. M.							6.25	2.25	14	2	14	1	14	7										
8	8 A. M.	88.7	55°	1 350	40	8	125	6.25	2.25	14	4	14	5	12	8	12	8	12	2	10	2	10	4	W.	Brisk.

FIG. 1.—WEIR CONSTRUCTION.

FIG. 2.—WATER ENTERING BASIN, SHOWING LINE OF DEMARCATION BETWEEN CLEAR AND MUDDY WATER.

When the process was put into operation, however, defects and new problems presented themselves in rapid succession and it soon became evident that a design for a permanent plant would have to await the solution of some of these problems. After three years of study and experiment, plans and specifications have been prepared for a fire-proof building, equipped with crushers, conveyors, elevators, feeders, mixing-tanks, etc. The contract for this building was let on June 11th, 1907, for the sum of $89 500, to be completed by January 1st, 1908. Plans, elevations and sections are shown on accompanying plates.

The building will contain eight circular bins, of 20 ft. inside diameter and 40 ft. high, for the storage of sulphate of iron and lime. These bins will have a capacity of 10 600 cu. ft. each, providing for the storage of about 160 days' supply of sulphate of iron and about 45 days' supply of lime, at the present rate of use.

The lime bins will be practically air-tight to prevent deterioration while in storage. In April, 1906, a small bin, 6 by 6 by 6 ft. interior dimensions, was built of wood with double walls, the space between filled with pitch to one-half the height, the upper half being lined with tar paper covered with pitch. This bin was filled with lime, and sealed. A careful watch was kept for signs of heating, but up to June 1st, 1907, no evidence of deterioration had been found. In August, 1906, another bin of the same size was built of concrete 6 in. thick, and filled with lime. No damage has occurred to the lime in this bin after ten months' storage. Both these bins have stood exposed to the weather, without any protection, ever since they were built.

The bins in the new building will be constructed of reinforced concrete, faced on the outside with brick. Sections showing the reinforcement are shown on Plate LXXVI. The central part of the building will be of brick, and divided into three floors, *viz.*, the basement floor where the crushers and a portion of the conveying machinery are installed; the pump floor, containing the heater tanks and pumps; and the mixing floor where the mixing tanks and daily supply hoppers with all their appurtenances are located. The motive power for crushers, conveyors, elevators, mixers, etc., will be electricity on a 500-volt circuit. All motors will be of the latest type, having commutating poles, and will be operated from one switchboard.

The daily supply hoppers will have a capacity of 900 cu. ft. and will be supported on four pairs of helical springs as shown on Plate

LXXVII. Each spring will carry a safe load of 10 000 lb., and deflect ½ in. under a load of 1 250 lb. The purpose of having this hopper move vertically is for automatic control of the conveyors feeding the hoppers. When the hopper is full, it will stand at its lowest elevation, but as the contents are withdrawn the hopper will rise, and, on reaching a certain point, will automatically switch in the current driving the motors which operate the feeding conveyors. As the hopper becomes filled again, it descends and again cuts off the current, stopping the feeding conveyors.

The lime is fed from its daily supply hopper into automatic scales, each of which dump the required amount into its tank, at regular intervals, varying from 1 to 4 minutes. The scales are designed to weigh any amount from 30 to 120 lb. at a single load, the frequency of dumping also being adjustable between intervals of 1 and 4 min., the two adjustments giving quantities varying at the rate of from 10 to 80 lb. per minute.

The sulphate of iron is delivered from its daily supply hopper into the solution tanks by the feeders previously described.

The milk of lime flows from the mixing tanks into one of the heating tanks on the pump-room floor and thence to the collecting tank from which it is taken by the pumps. The collecting tank is supplied with a varying quantity of cold water, controlled by a float valve, for the purpose of cooling and diluting the milk of lime, and also for increasing the volume of dilute milk of lime, so that the pumps shall not empty the tank at any time because of the varying quantity of milk of lime flowing from the mixing tanks, or because of the variable speed of the pumps themselves on account of variation in voltage of the current supplied.

The conveyors and elevators are shown in plan and elevation on Plates LXXVIII and LXXIX, and Fig. 3. The lump lime is unloaded from the car into the crushers, A and B, on the east side of the building. It is crushed to ½ in. and smaller, and carried by Conveyors A and B to Conveyor C, which dumps it into the boot of Elevator D, by which it is elevated to Conveyor E, which runs above the lime storage bins and dumps into these bins through doors provided for that purpose.

In taking lime from the bins for daily use, the crushed lime feeds by gravity into Conveyor F, which delivers it to Elevator G, which,

Fig. 1.—Interior of Coagulant House, June 19th, 1905.

Fig. 2.—Interior of Coagulant House, April 9th, 1907

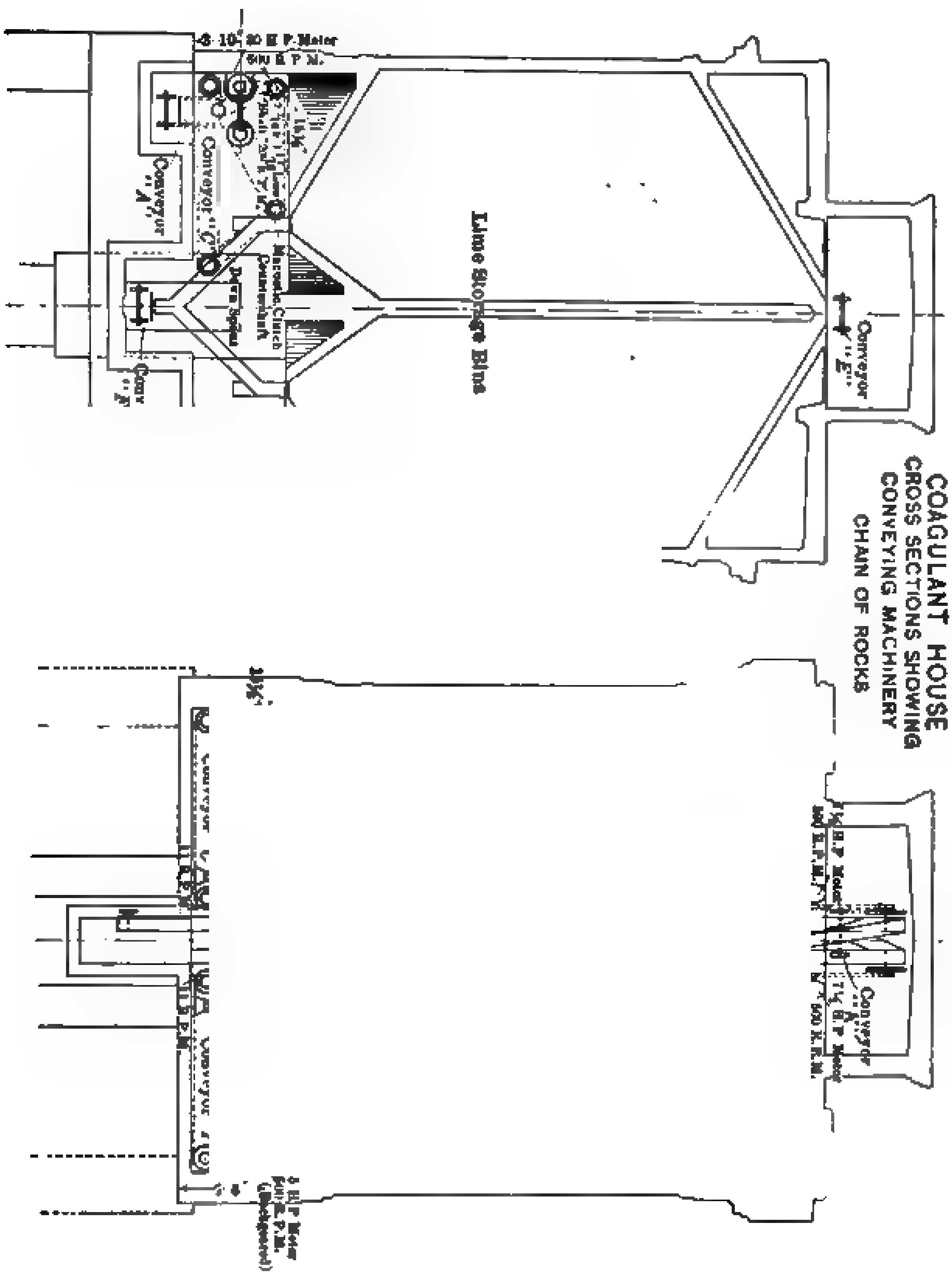

COAGULANT HOUSE
CROSS SECTIONS SHOWING
CONVEYING MACHINERY
CHAIN OF ROCKS
Lime Storage Bins
Conveyor "E"

FIG. 8.

in turn, carries it up to the lantern and delivers it to the daily supply hopper.

The sulphate of iron will be unloaded from cars on the west side of the building by an automatic power shovel into Conveyor H, whence by Conveyors H and I, Elevator J and Conveyor K, it will be delivered into the storage bins. It will be taken from the bins by the same method as the crushed lime, by Conveyor L and Elevator M, to the daily supply hopper. As before mentioned, the motors driving the conveyors and elevators feeding the daily supply hoppers will be started and stopped automatically by the vertical motion of the hoppers. The daily supply hoppers will each carry from 50 000 to 60 000 lb. of material, which is sufficient for from 2 to 2½ days' supply of sulphate of iron, and from 16 to 20 hours' supply of lime, at the present rate of use.

In case any of the machinery feeding the daily supply hoppers breaks down, provision is made for drawing either sulphate of iron or lime, or both, from the bottoms of the bins into small cars on the basement floor, from which they will be elevated by the freight elevator, shown on Plate LXXX, to the mixing floor, when the tanks will be fed by hand, as is being done at the present time.

The cost of operating the new plant is estimated at $17 000 per year, including interest and depreciation, as compared to $21 500, which has been the average cost of operation for the past three years. The actual yearly cost of operation alone of the new plant will be at least $9 000 less than that of the original plant.

There are now being built two new settling basins, Nos. 7 and 8, having a capacity of 75 000 000 gal., at a cost of about $500 000. These basins are constructed with reinforced concrete walls of sections shown on Plate LXXXI. The walls are backed with clay puddle 18 in. thick. The floor is covered with 9 in. of concrete, in blocks 8 ft. square, on 18 in. of clay puddle, the joints between the blocks being filled with an asphalt filler.

These basins are located as shown on Plate LXXXII, and are connected to the drawing conduit, the by-pass, and Basin No. 6, in such manner that the flow of water may be changed according to any desired direction, thus making the operation of the settling basins perfectly flexible and adaptable to any conditions which may arise. Basin No. 8 is connected with the filling chamber by a 7-ft. steel-pipe con-

FIG. 1.—PRESENT COAGULANT HOUSE.

FIG. 2.—NEW COAGULANT PLANT.

nection, so that the raw water may be introduced directly into it, making it a primary settling basin if desired, and when Basin No. 6 is made the primary settling basin, clear water may be drawn from Basin No. 1 through the 7-ft. pipe into Basin No. 8, thus making Basin No. 7 the final basin from which the treated water is drawn. With these basins in service and the improved facilities for uniform treatment afforded by the new coagulating plant, there is no reason to doubt that St. Louis will be supplied with water as agreeable to the eye and as pure and wholesome as is enjoyed by any city in the United States.

From the inception of the first idea of the St. Louis process of clarifying and purifying the water supply, the work has been prosecuted with all the energy and skill of the Department, individually and collectively. No one man, apart from the Water Commissioner himself, who, of course, has borne the greatest portion of the responsibility of success or failure, can be considered to be entitled to more credit for its success than any other employee engaged upon that particular work. It would not be just to conclude this article without mentioning the valuable and efficient services of Mr. Arthur I. Jacobs, Engineer in Charge of the Supply and Purifying Division, and Mr. Wilson D. Monfort, Chemist of the Department, both of whom have contributed largely to the success of the process.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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GAS ENGINES.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"(*a*) What is the best apparatus and most economical system for cleaning producer or furnace gas, to be used in gas engines?

"(*b*) To what extent is ordinary producer gas, made from bituminous coal, used in gas engines, and what practical results have been obtained by any methods for removing tar or soot?"

BY TIMOLEON GEELEN, ESQ.

Mr. Geelen. TIMOLEON GEELEN, ESQ. (by letter).—The following discussion relates principally to the development of gas generators in Europe.

Besides illuminating gas, which is too costly for heating purposes, two other kinds of gas have been in use in Europe for a long time, namely, Siemens gas, and water gas.

Siemens gas is produced by the incomplete burning of cheap coal in a high furnace, and consists principally of carbon oxide and nitrogen.

1 kg. of carbon, by combustion into carbon oxide (CO), produces 2 400 t. u. (4 320 B. t. u. per lb.).

1 kg. of carbon, by combustion into carbonic acid (CO_2), produces 8 000 t. u. (14 400 B. t. u. per lb.).

The highest possible efficiency practically obtainable, therefore, is $\frac{8\,000 - 2\,400}{8\,000} = 0.7$.

* Continued from August, 1907, *Proceedings*.

Mr. Geelen.

As the temperature of the Siemens furnace is very high, the gas is not exactly suitable for power purposes, as it needs to be cooled, and therefore the efficiency of the generator is small. Water gas seems to be more suitable. It is produced by passing steam through burning coal, and consists principally of carbon oxide and hydrogen.

$$C + H_2O = CO + 2H.$$

12 kg. of carbon require for their combustion 16 kg. of oxygen or 18 kg. of water, thus corresponding to 1 kg. of carbon to 1.5 kg. of water.

1 kg. of carbon, by combustion into CO, produces 2 400 t. u. (4 320 B. t. u. per lb.).

1.5 kg. of water requires by decomposition $1.5 \times 3\,200 = 4\,800$ t. u. ($1.5 \times 5\,760 = 8\,640$ B. t. u. per 1.5 lb.).

This shows that a water-gas furnace does not produce heat, but, on the contrary, consumes heat. For this reason, such a furnace cannot work continuously, but must be blast warm after having cooled itself. For a regular service, at least two furnaces are necessary, and these have to work alternately. The reversion, which is necessary every few minutes, makes the service very incommodious.

Water gas consists of equal parts of carbon oxide and hydrogen. The molecular volume of each of the two kinds of gas is 23.13. The formation heat of water is 58 100 t. u., of carbon oxide, 29 000 t. u., and of carbonic acid, 96 960 t. u. The heating value of the pure water gas, therefore, will be:

$(58\,100 + 96\,960 - 29\,000) \div (2 \times 23.13) = 2\,730$ t. u. per cu. m. (306 B. t. u. per cu. ft.).

The reaction in the Siemens furnace is: $C + O = CO$. As this furnace does not receive oxygen, but atmospheric air, a quantity of nitrogen also enters the process, namely:

$$\frac{0.787}{0.213} \times \frac{1}{2} \times 23.13 = 42.71 \text{ cu. m.}$$

The calorific value of the gas, therefore, is:

$(96\,960 - 29\,000) \div (23.13 + 42.71) = 1\,030$ t. u. per cu. m. (115 B. t. u. per cu. ft.).

It seemed advisable, therefore, to make a combination of the two processes, and introduce a mixture of air and steam in the furnace. The necessary heat for making the water gas is then furnished by the formation of the Siemens gas, and therefore the furnace can work continuously, the reaction being:

$$C + O = CO; \; C + H_2O = CO + 2H.$$

In addition to 23.13 cu. m. of hydrogen and 46.26 cu. m. of carbon oxide, the gas will also contain 42.71 cu. m. of nitrogen, as already mentioned; therefore, the 112.1 cu. m. of gas will contain

Mr. Geelen. 41% of carbon oxide, 21% of hydrogen and 38% of nitrogen. Its calorific value will be:

$[58\,100 + 2\ \ (96\,960 - 29\,000)] \div 112.1 = 1\,700$ t. u. per cu. m. (190 B. t. u. per cu. ft.).

The Englishman, Dowson, was the first to introduce an arrangement to produce such mixed gas, about 1885. At first he used anthracite as fuel, which gave him a pure gas; later, he also used coke. Fig. 4 shows the general arrangement. The water is evaporated in the boiler, *A*. The superheated steam passes through the suction air blast, *a*, and the mixture of air and steam passes under the grate. The gas produced in the generator, *B*, passes the cleaner, *C*, then through the scrubber, *E*, and the saw-dust cleaner, *D*. The gas then passes into the receiver.

DOWSON'S GAS PRODUCER

FIG. 4.

An attempt has been made to use the Dowson system by utilizing the heat of the gas which leaves the generator, and in this way an efficiency of 75% has been obtained. This means that the calorific value of the gas is equal to three-fourths of that of the carbon from which it has been produced.

The most important simplification in the construction of gas generators is that of Bénier, dating from about 1895. Instead of introducing the air by a steam blast, as in Dowson's arrangement, Bénier leaves the function of introducing the air to the engine itself, establishing in this way the well-known suction-gas arrangement. Fig. 5 shows the general arrangement of such an installation.

The evaporator forms a part of the generator, and the water is heated to a temperature of from 80 to 90° cent. by the passing gas.

This evaporator is in communication with the atmospheric air Mr Geelen. through an opening, *e*. The entering air strikes the surface of the heated water and, after being saturated with water vapor, passes under the grate. The evaporator is provided with an overflow conducting the water into the ash-pit where it extinguishes the ash and also partly evaporates, thus contributing to the formation of gas.

A further change in the general construction of gas generators was made by Taylor, who separated the evaporator from the generator, resulting in the arrangement shown in Fig. 6.

Gas generators have also been constructed without the evaporator, the water being injected in small quantities which evaporate immediately. The advantage of this combination is that it is not

FIG. 5.

necessary to wait until the water in the evaporator has reached the required temperature before the machinery can be put into operation. Fig. 7 shows a generator of this kind.

The air enters the hollow cover of the generator at *a*, where it is heated, and then passes into the space, *b*, where it is heated still more by the gas. Into this space the water is injected and evaporates immediately, the mixture of air and water vapor being conducted under the grate through the pipe, *d*.

To adapt the quantity of injected water to the working suction of the engine, the generator is provided with a feed-water regulator, shown in Fig. 8. This regulator consists of an open receptacle into which water enters at *h*, and from which water flows to the evaporator through the valve, *i*. This valve is supported by the

Mr. Geelen.

SUCTION-GAS PRODUCER PLANT WITH SEPARATE EVAPORATOR

Fig. 6.

Fig. 7.

flexible plate, *k*, which is the bottom of the box, *l*. The lift of this plate is limited by the screw, *m*. The box, *l*, is connected with the suction pipe of the engine. The stronger the suction, the higher the plate, *k*, will be lifted, and the more water will flow to the evaporator through the valve, *i*. Mr. Geelen.

After leaving the generator the gas requires cleaning, and this is generally done in the different apparatus described hereafter.

At first the gas passes a receptacle filled with water, where it loses a portion of the dust it contains. Afterward it passes an apparatus generally called a scrubber. This is a high cylindrical receptacle filled with coke, the gas entering through an opening near the bottom. In passing upward it meets a spray of water

FEED-WATER REGULATOR

FIG. 8.

which cools it. In this apparatus the gas loses also a large portion of the tar it contains.

Another apparatus for cleaning the gas is the so-called condenser. It consists of a number of perforated plates placed in such a way that the gas passing through a hole of one plate strikes the unperforated part of the next plate, thereby losing a portion of the tar it contains.

If the fuel used contains much tar, the gas is forced to pass another cleaner, where it is purified on its way through a bed of saw-dust.

The installations which have been mentioned are only limited to the use of anthracite, coke or charcoal, having a consumption

Mr. Geelen. of from 400 to 600 g. per h.p. per hour, according to the quality of the fuel.

Fuel containing much tar, and also other cheap bituminous coal, cannot be used continuously with good results in these generators, and therefore constructors have been endeavoring to discover other arrangements better adapted to the use of such fuels.

The first to succeed in installing a large plant of this kind was Dr. Mond, in England. To avoid the baking of the fuel and the formation of clinkers, he introduced large quantities of steam into the generator, and burned the heavy tar-containing gas by forcing it to pass the hot fuel bed of the generator. The whole arrangement has a large calorific loss, and can only be executed on a large scale, because it cannot be worked with profit unless it is combined with an installation for the production of ammonia sulphate, the whole system being thus very complicated. Notwithstanding this inconvenience, the installation has given satisfactory results during ten years of service, and a new 12 000-h.p. plant, working with Mond gas, has been installed recently in Madrid.

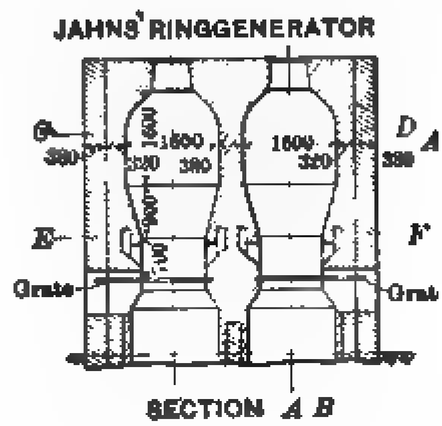


Fig. 9.

Quite a different system has given satisfactory results in Germany. This arrangement, called Jahn's ring generator, is working with the poorest coal, even with the so-called "Klaubeberge."

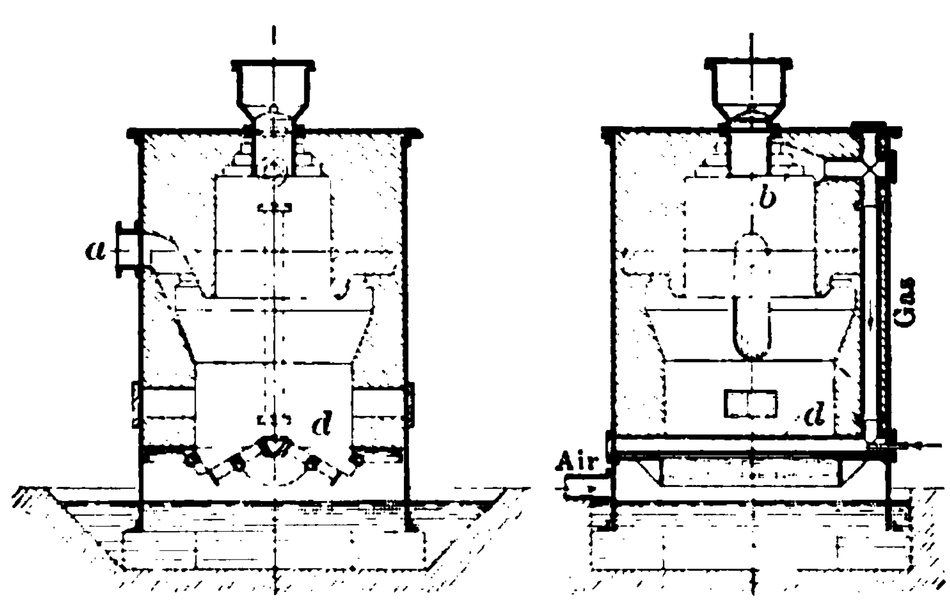
As seen from Fig. 9, Jahn's ring generator is composed of four generators working in one group. They are taken into service one after the other, and the gas of the third and fourth is led through the first and second, which are already burning well. In these generators is found a real formation of gas, and, besides this, the combustion and decomposition of the heavy tar-containing gas. When the fuel-contents of the first generator of the group, which has been longest in service, are no longer sufficient to aid in the process, this generator is put out of service, after being entirely exhausted. It is then cleaned and recharged, and is again connected to the other generators, the other three advancing correspondingly in the process.

It must be stated, however, that this system, also, is only possible for large installations. Mr. Geelen.

The modern construction of nearly all generators for the use of bituminous coal, lignite or turf, is based on the same principle, that of changing the fuel first into coke, and afterward gasifying this coke. The gas formed by the coking of the fuel contains much tar; this is decomposed, and the gas is made "permanent" by passing it through a bed of incandescent fuel in the generator.

The fuel column in these generators is made high, and the gas when produced leaves the generator in the middle of the column. The fuel in the upper part of the generator is coked, and the gas thus formed is led under the grate, being forced to pass the hot fuel bed of the generator, where it is made permanent. There is no loss in this process, as the carbonic acid and the water formed by the combustion are again reduced to carbon oxide, hydrogen, and oxygen.

Fig. 10 shows the details of a generator of this kind.



DANIELS' GENERATOR
FIG. 10.

The gas is sucked off at *a;* the distillation gas produced in the upper part of the generator, *b,* falls through the pipe, *i,* into the pipe, *d,* the latter ending in the middle of the grate. Into this pipe steam is also introduced. The distillation gas is thus forced to pass the fire, and is made permanent.

A different arrangement to obtain the same effect is made by the construction of the so-called "double-working generators." They have two burning zones, one on the grate below, the other at the top of the fuel column, while the gas is sucked off in the middle of the column.

The fuel at the top of the column is at first coked, then passes into the upper burning zone, is extinguished on its way downward, and is finally consumed over the grate. The distillation gas formed in the upper part is sucked through the upper burning zone and is thereby made permanent.

Mr. Geelen

Fig. 11 shows a type of these generators.

It seems, however, that these generators also have not given entirely satisfactory results where coking coal is used, and it has been necessary to use efficient mechanical arrangements in their upper parts to prevent this baking.

One kind of bituminous coal has proved excellent for use in the double-working generators, this fuel being lignite.

Lignite is obtainable almost everywhere at a very low price. In 1902 the Gasmotorenfabrik Deutz, Germany, constructors of the Otto engines, had installed at the Düsseldorf Exhibition a suction-gas plant which worked with lignite. This installation is still in operation, and is giving entirely satisfactory results.

GENERATOR OF THE GASMOTORENFABRIK DEUTZ

Fig. 11.

In general, the suction-gas process, with lignite as fuel, is very simple. Lignite does not bake together, and the tar in the gas is not of as much importance as the tar in the gas from ordinary coal. The only inconvenience is the bad quality of the water leaving the cleaning apparatus.

In Germany lignite briquettes are used to a great extent, and have given excellent results. While the common lignite has from 40 to 60% of water and a calorific value of from 2 000 to 3 800 t. u. (from 3 600 to 6 840 B. t. u. per lb.), the lignite briquettes have less than 20% of water and a calorific value of about 4 800 t. u. (8 640 B. t. u. per lb.).

Fig. 12 is an illustration of a lignite generator.

Turf, also, can be used in the double-working generator; and even poor classes of turf, with from 40 to 50% of water, can be used

advantageously. Turf gives from 1.3 to 1.8 cu. m. of gas per kg. Mr. Geelen. (from 21 to 29 cu. ft. per lb.), corresponding to an average calorific value of from 1 350 to 1 499 t. u. per cu. m. (from 2 400 to 2 500 B. t. u. per cu. ft.).

Fig. 13 represents a generator for the use of turf.

The shaft consists of two parts, the upper and wider part being provided with two grates, and the lower and narrower part with the ordinary grate. During the service the turf burns only at the border of the upper grate. The inner part of the fuel column does not burn but sinks gradually downward, thereby being coked. The gas produced in the upper part of the generator passes through the hole, *c*, and the pipe, *d*, under the grate; then it goes through the burning zone, and is sucked off through the hole, *e*.

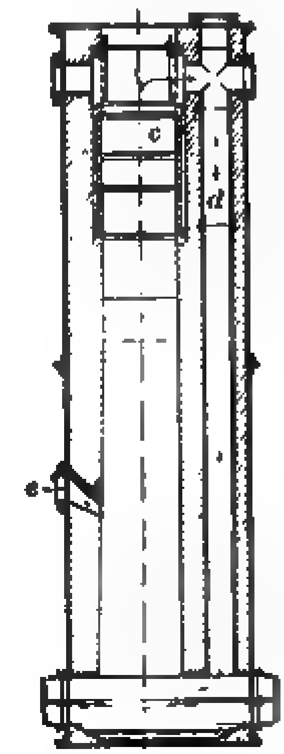
GENERATOR OF THE GASMOTORENFABRIK DEUTZ

Fig. 13.

Another generator may be mentioned, namely, that of Riché, which is especially adapted for the gasification of wood. It must be stated, however, that wood alone does not give good results in service, and that a second fuel, carbon, is necessary to aid in the process. Fig. 14 shows the general arrangement of this generator.

It is composed of two shafts, the first serving as a feeding reservoir for the grate, *b*, on which the wood is burning, the second being filled with charcoal for the reduction of the produced carbonic acid. The tar-containing gas passes the fire, over the grate, and is thus burned and reduced to carbon oxide by the burning charcoal. The gas is then cooled in the pipes, *d* and *e*, by injected water.

Mr. Geelen. The idea of using two different kinds of fuel is also brought out in the generator of Lencauchez. However, instead of using two different generators, he uses only one for both kinds of fuel, as shown in Fig. 15.



KOERTING'S TURF-GENERATOR

FIG. 13.

RICHÉ'S WOOD-GENERATOR

FIG. 14.

Gas coal is introduced into the generator through the hole, *a*, coke is introduced through the hole, *b*. The water is evaporated in the ash-pit. The gas produced is forced to pass the burning bed of coke, thus being reduced. The holes, *d* and *c*, will give black

smoke, while the hole, *c*, is giving colorless gas. This generator is especially designed for heating purposes. From 75 to 80% of gas coal requires from 25 to 20% of coke. Mr. Geelen

The arrangements for cleaning the gas produced in the generators described are the same as those already mentioned in connection with the anthracite and coke generators.

It is not the writer's intention to give a full description of the great number of gas generators on the market. Nearly all these are based more or less on the principle already mentioned, namely, that of changing the fuel first into coke, which is then gasified, the tar-containing gas being forced to pass an incandescent bed of fuel, where it is made permanent.

The coke furnaces and high furnaces are generators of quite a different class. In Germany there are two different classes of coke furnaces. The first is the so-called "Flammöfen," which are heated

LENCAUCHEZ' GENERATOR

Fig. 15.

with all the gas the furnace produces. The heat of the burned gas, which has a temperature of 1 100° cent., is used everywhere for heating boilers. The result obtained therewith is, that for every kilogram of coal put into the furnace 1.2 kg. of water can be evaporated, thus regaining about one-sixth of the heat of the coal.

The second class of coke furnaces contains the so-called "Nebengewinnungsöfen," which deliver not only the hot burned gas but also coke gas. The gas leaving the coke furnace is first cooled, then it is separated from the tar, ammonia, benzol, etc., which it contains, and is then returned partially to the furnaces, where it heats them, the heat of the burned gas being utilized under steam boilers. The remaining gas could be utilized in gas engines, but it is also generally used to heat steam boilers. The quantity of this gas depends mainly on the quality of the fuel, and especially on the water it contains.

The combined heat of the burned gas and the coke gas of the "Nebengewinnungsöfen" does not evaporate as much water as the

Mr. Geelen. heat of the burned gas of the "Flammöfen" alone, being only from 0.8 to 0.9 kg. of water per kg. of coal. Two-thirds of this belongs to the burned gas, and one-third to the remaining coke gas.

If it is intended to dispose of the largest possible quantity of coke gas for use in gas engines, and thus not use the heat of the burned gas for heating steam boilers, the coke gas leaving the furnace is led into the so-called "Regeneratif" furnace. The quantity of gas which can be disposed of by using this furnace is from 100 to 140 cu. m. per ton of coal.

It is now a question of great interest to know how the highest possible horse-power can be obtained from the disposable heat. Experience has shown that nearly the same capacity is obtained in the three following cases:

1.—By utilizing the entire heat of the burned gas of the "Flammöfen" in modern steam boiler plants;

2.—By utilizing the heat of the burned gas of the "Nebengewinnungsöfen" in steam engines or turbines, and the remaining gas in gas engines;

3.—By utilizing the whole amount of gas of the regenerator furnace in gas engines.

At first sight it seems to be strange that, using a regenerator furnace and gas engines, it is not possible to produce a larger capacity. But the fact that a large amount of heat is lost through the chimney of the regenerator furnace has to be taken into consideration.

If only the "Nebengewinnungsöfen" are considered, about one-third more capacity can be obtained by installing a combined steam and gas plant, than by installing a whole steam plant; but the service is somewhat difficult with such a combined system, and will only give satisfactory results in large plants.

For this reason it must not be thought strange that, for instance in Germany, gas engines working with coke-furnace gas are not yet used to any great extent. If other arrangements are successful in obtaining more disposable gas from the regenerator furnaces, the coke gas engine will make its way as rapidly as the high-furnace gas engine.

In the high furnace the conditions are much more favorable, as it delivers considerable quantities of gas. However, in composition, coke-furnace gas and high-furnace gas are quite different. Coke-furnace gas, produced by the gasification of coal, contains principally methane (CH_4) and hydrogen, and has a very high calorific value of about 4 000 t. u. per cu. m. (448 B. t. u. per cu. ft.).

High-furnace gas, on the contrary, is a poor gas, and contains only one-third of combustible substances, especially carbon oxide

(CO), and has a calorific value of only from 800 to 900 t. u. per cu. m. (from 90 to 100 B. t. u. per cu. ft.). Mr. Geelen.

High-furnace gas requires but little air in its combustion, about its own volume; coke-furnace gas requires from 5 to 6 times more air, and, notwithstanding this, the mixture is about 20% stronger than the high-furnace gas mixture, so that coke-gas engines could be built smaller than high-furnace gas engines. This is principally due to the hydrogen contents in coke-furnace gas.

Generally, however, the dimensions of each kind of machinery are made the same, taking into consideration an average indicated pressure of 4.8 atmospheres (about 70 lb.). The only difference in their construction is that the compression in the cylinder is different for the two kinds of gas, being for high-furnace gas at least 12 atmospheres (about 185 lb.), and for coke-furnace gas only 8 atmospheres (about 115 lb.).

The cleaning of these gases is of the greatest importance, and a distinction has to be made if the gas is to be used only for heating purposes or for gas-engine service. In the first case the dust contained in the gas may be about 0.5 g. per cu. m. (about 0.0003 lb. per cu. ft.), in the second case only a quantity of 0.02 g. per cu. m., or less, is admitted (about 0.0000013 lb. per cu. ft.).

However, as the better-cleaned gas has also given better results in steam-boiler plants, the same cleaning process is generally adopted at the present time for both cases of utilizing the gas.

The coke-furnace gas has its principal cleaning during the process of separating the tar, ammonia, benzol, etc., and has only to be cleaned of the remaining tar, sulphur and cyanide.

High-furnace gas has to be separated principally from the dust it contains.

The remaining tar in coke-furnace gas is separated by passing the gas through a coke-scrubber and afterward through a drying apparatus. Sulphur and cyanide are separated by passing the gas through an apparatus containing "Raseneisenerz," a carbonic iron ore. If the gas is not freed sufficiently from sulphur, it may soon be observed by the corrosion of the piston rod, valves, and other parts.

The separation of dust from high-furnace gas requires a considerable amount of force, being about 2% of the capacity of the working machinery. The general principle followed in this cleaning process is, to force the dust into the water, with which it is then removed.

An apparatus of this type, very much used in Germany is the centrifugal cleaner of Theisen, the construction of which is shown in Fig. 16. Besides this, a number of centrifugal cleaners have been put on the market, also a certain type of ball mill.

Mr. Geelen. As already stated, the gas in these cleaning apparatus is freed from dust, so that it contains not more than 0.02 g. per cu. m. (0.0000013 lb. per cu. ft.). Therefore it contains less dust than the surrounding air in the working plant. As a final cleaner, a slack-wool, or a saw-dust, cleaner is used.

The great importance of the use of coke-furnace gas and high-furnace gas is seen clearly, if an approximate calculation is made in reference to the capacity of coke and high furnaces.

During 1906 the production of coke in Germany was about 20 000 000 tons, corresponding to about 27 000 000 tons of coal.

For calculating the capacity which can be obtained from the disposable heat, we accept, per horse power per hour, in modern

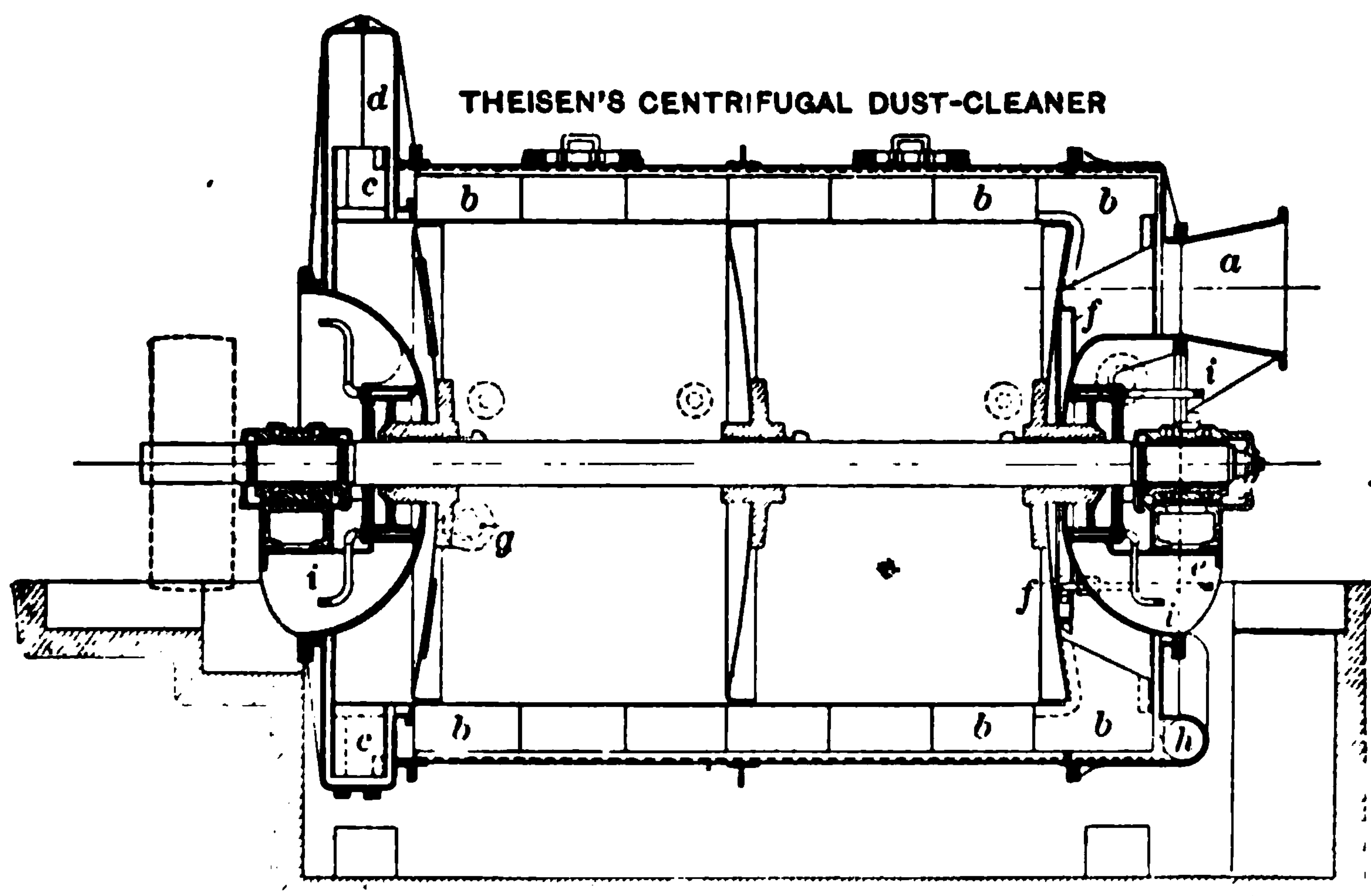


FIG. 16.

steam engines or turbines, 6 000 t. u. (about 1 500 B. t. u.) or 6 kg. (13.2 lb.) of superheated steam; and for modern gas engines, 3 000 t. u. (about 750 B. t. u.). In these figures all possible losses are included.

Taking this into consideration, we find for coke furnaces a disposable capacity of about 560 000 h.p. in combined steam engines and gas plants, or in pure gas plants.

Still more favorable conditions are found with high-furnace gas.

The iron production during 1906 in Germany was about 12 000 000 tons. Per ton of iron produced, 5 000 cu. m. of gas are produced (176 585 cu. ft.), with an average calorific value of about 800 t. u. per cu. m. (about 90 B. t. u. per cu. ft.). Of this quantity, 2 500 cu. m. are required to heat the air, thus leaving the remaining

2 500 cu. m. for use in gas engines. According to this, we find a disposal capacity of 1 000 000 h.p. in gas engines, or a capacity of 500 000 h.p. utilizing the gas in modern steam engines or turbines. Thus the total capacity which can be obtained in Germany alone by utilizing coke-furnace and high-furnace gas is about 1 500 000 h.p. **Mr. Geelen.**

In the United States, where the production of coke and iron is much greater than in Germany, still more surprising figures may be found.

Coke-furnace and high-furnace gas received only special attention after the successful construction of large gas engines of a practical type. The construction of these engines was begun about 1890, and the makers encountered many difficulties. Nearly all constructors took the small gas engine (and the good results obtained with it) as a model for the construction of the larger types, and it was especially the construction of the cylinder head which caused the greatest difficulty; but, after abandoning this method of construction, and taking into consideration the results obtained in building large steam engines, they succeeded at last in making large gas-engine units, which would work under complete guaranty.

It is not the writer's intention to describe the very interesting details of the construction of these large gas engines. He will only state here that the largest gas engines yet built have a maximum capacity of from 1 000 to 1 500 h.p. per cylinder, and that the total maximum capacity of engines built in tandem-compound arrangement has been 3 500 h.p.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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THE EFFECTS OF THE SAN FRANCISCO EARTHQUAKE OF APRIL 18TH, 1906, ON ENGINEERING CONSTRUCTIONS.

Discussion.*

By Langdon Pearse, Jun. Am. Soc. C. E.

Mr. Pearse. Langdon Pearse, Jun. Am. Soc. C. E. (by letter).—The writer would like to obtain information relative to concrete exposed to the continued heat of a furnace, or to hot flue gases, as in a chimney. Such information would throw some light on the wearing qualities of concrete as a fire resister. In the design of a flue for the new Scioto River Pumping Station at Columbus, Ohio (under the direction of John H. Gregory, M. Am. Soc. C. E., Engineer-in-Charge), there came up the question of exposing a concrete face to flue gases. A search of the literature on the subject gave little information, and finally it was decided to build the flue of a special concrete, using brickbats instead of crushed limestone for ballast, the flue to be lined inside with one thickness of fire-brick, and covered outside with pressed brick to match the wall of the boiler-room. This flue was 4 by 12 ft. inside, and cared for Babcock and Wilcox boilers having a total capacity of about 1 200 h.p.

The writer would also like to point out the utility of reinforced concrete columns built up of structural shapes securely riveted together, the steel being calculated to carry all the dead load and the concrete all the live load. If suitable connections be devised to catch the floor and beam rods, the difficulty of filling the column with a mass of

* Continued from August, 1907, *Proceedings*.

horizontal rods can be avoided. Such a detail was worked out for the new McGraw Building in New York City. Or steel columns, calculated to carry all the load, dead and live, with a concrete cover and filling for fire protection only, may be used. Generally, architects desire small columns, sometimes asking for dimensions which are impractical in reinforced concrete as commonly designed unless very high working stresses are allowed. Mr. Pearse.

The use of steel column framing permits the use of smaller columns, puts the metal in far better shape to resist flexure, and removes all danger of poor columns caused by pouring a deep column packed full of round rods.

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WATER SUPPLY.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"Is it better policy to purchase and control water-sheds, thereby preventing the pollution of impounding reservoir supplies, or to suffer a certain amount of pollution of such supplies, relying upon filtration to correct the effects thereof?"

BY MESSRS. WILLIAM J. BALDWIN, GARDINER S. WILLIAMS, J. T. NOBLE ANDERSON, WILLIAM B. FULLER, J. WALDO SMITH, AND PABLO SOLÍS AND OCTAVIO GUZMÁN.

Mr. Baldwin. WILLIAM J. BALDWIN, M. AM. SOC. C. E.—Some 25 or 30 years ago, small filters were recognized as propagating beds. The speaker would like to ask whether there is anything in this, and what engineers know about it?

Mr. Williams. GARDNER S. WILLIAMS, M. AM. SOC. C. E.—It may be proper to say a word in regard to the kinds of bacteria that are to be dealt with, particularly in view of the statement of one of the speakers, that owing to the absence of light the number of bacteria may be very decidedly reduced in passing through a water-works system. It is to be borne in mind that those bacteria which are most dangerous to the human organism thrive in the darkness, to most of them light is germicidal, so that the above-cited condition would fail almost entirely to reduce the forms of bacteria which are in any way dangerous to health.

The subject of railroad pollution is certainly a serious one, as it can readily be seen that closing the closets while traversing water-

* Continued from August, 1907, *Proceedings*.

sheds might, in time, entail closing them altogether, and it seems that the more rational method of dealing with the question is either to provide receivers upon the cars for the dejecta, or to install such systems of drainage along the railroads as will divert the contamination from the water-shed. Mr. Williams

It may be quite safely stated that while there is no question that a great deal can be done to improve a water supply by eliminating the sources of evident pollution from the water-shed, yet no such system will ever be perfect. It will never be possible to remove all such sources, and while the elimination of as many of them as possible is to be advocated, a community is not thereby warranted in using a surface water subject to possible pollution, without filtration. On the other hand, the mere filtration of the water or the mere existence of a filter operated by anybody is not a reliable safeguard. Whether the filter be of the slow-sand, or of the so-called rapid or mechanical type, it needs very close attention, and unless that careful watchfulness accompanies the operation, one cannot depend upon it any more than upon the ownership of a water-shed. A filter is a very delicate machine, and it must be carefully and skilfully handled.

It can be quite definitely asserted that, for a properly operated filter, there is no such thing as its becoming a propagation bed. The mechanical filter which is not washed at proper intervals will, of course, permit of the passage of bacteria by becoming filled, since the sand bed in such a filter operates simply as a strainer, and when the strainer is filled the material washes out at the bottom. In a slow-sand filter, however, there is no record known to the speaker of the condition suggested, in the 70 years' experience with that type; and with a mechanical filter, properly attended, nothing of the sort has ever occurred.

J. T. Noble Anderson, M. Am. Soc. C. E.—The speaker wishes to call attention to a point in Mr. Fuller's discussion, which must be due to some misapprehension on his part. He says that the water-sheds of several cities, among which he mentions Manchester, England, have been acquired at a cheap price. The speaker was employed many years ago on the Manchester water scheme, and also on that of Belfast, Ireland, and knows that the prices paid at both places were not what would be called cheap; for example, much of the Manchester watershed was acquired from the Fleming family, who asked $2 500 per acre for the land. The Manchester Corporation offered $100 per acre —the great difference is manifest—and it was purchased for from $400 to $500 per acre. Mr. Anderson

In the case of the Belfast water-works the average price originally paid for the land was about 10 shillings per acre per annum, which was the rental price paid by the farmer. This, with some other items, made the net return of the land required by the Belfast Corporation about $5 per acre per annum. With the compensation paid to the

Anderson. tenant and that paid to the landlord, the land cost the Belfast Water Board on an average of from $200 to $250 per acre.

There is another point which has come up in Australia, and which the speaker thinks has been generally overlooked by writers on hydraulic subjects, and that is, the use of the acquired water-sheds for re-foresting, especially in sub-tropical countries. The cutting down of forests interferes greatly with the rainfall, therefore it is not only important, in many countries, to protect the water-shed from impurity, but also to protect it from natural conditions, so that the rainfall of the range in which the water-shed is situated will not be impaired. By the judicious planting of these water-sheds that result is obtained, and the rainfall may be actually increased and a revenue earned. In the State of Victoria, the City of Melbourne has a water-shed roughly estimated at 100 sq. miles of forest, that will suffice to supply a population of 750 000, which it is expected will be reached within the next 8 or 10 years, and the Government has further reserved 250 000 acres all of which will be conserved ultimately and used by the Melbourne Water Commission. The point is an exceedingly important one on the subject in hand.

Mr. W. B. Fuller. WILLIAM B. FULLER, M. AM. SOC. C. E.—The speaker believes that all upland water supplies should be filtered, even though filtration is put in merely as a safeguard. Where it is suspected or known that pollution exists on an upland water-shed, the proper course to pursue is, first, to put in a filter, and then, if further funds are available, to buy up and remove the polluted portions of the water-shed.

While it is true, as has often been said, that "innocence is better than repentance," it must be recognized at the outset that no upland water supply, about which there could be any question regarding the necessity of buying up any portion of its area, can be pure; and unless the entire area is inaccessible to Man and beast, we have the ever present possibility of outside contamination of even the purest supplies.

Some of these possible sources of pollution have been pointed out, notably the contamination possible from railway trains traversing the water-shed and the need of keeping the closets closed during such times.

Passing over the difficulties and inconveniences attending the carrying out of such orders and the dangers present, supposing negligent attention on the part of the railroad officials, there are other sources of pollution of an inhabited region still more difficult to regulate, as, for instance, during the repair, construction, or reconstruction of railroads and roads where large numbers of laborers pollute the adjacent fields, the construction of country estates, the pollution by campers, picnickers and other nomadic hordes, and many other possibilities.

It is true that large impounding reservoirs assist greatly in reduc-

ing the gross and accidental pollutions mentioned, but the standard of purity now demanded in many communities will not stop at one possible means of correction, but demands the best correction that engineering science can offer. To this end the best and safest guard against both accidental and permanent pollution is a properly designed and scientifically operated filter, the filtered water passing directly into covered conduits and not again exposed to the air, or possible contamination, until it reaches the tap of the consumer. Mr. W. B. Fuller.

In advocating filtration the speaker does not wish to be understood as considering it a sure specific for all water evils, and he certainly advocates, first, the securing of the purest water supply from the least polluted upland possible; and, second, the keeping of this upland supply as pure as possible before delivery to the filters. To this end, he is a firm believer in the necessity of draining all stagnant and marshy places; the removal, by purchase or otherwise, of undesirable persons and manufacturers from the water-shed; the organization and efficient maintenance of sanitary patrol; and the taking of all possible precautions against pollution. The less the filter has to do, the safer the water, but the filter should stand at the outpost and guard against enemies that slip in unawares, as well as against those that are known.

J. Waldo Smith, M. Am. Soc. C. E.—A large impounding reservoir at the lower limit of a water-shed is, from a sanitary point of view, one of the greatest safeguards which can be provided for a water supply. The sanitary quality of a water is undoubtedly increased by long periods of storage, though the storage may have but little effect on either its taste or appearance. In fact, the physical quality of a water may be made worse by storage, and for this reason as well as to satisfy the proper public demand for a water, clear, and pleasant to look at, filtration is necessary. Mr. J. W. Smith.

The question as to whether or not conditions in a storage reservoir can be improved by stripping its bottom and sides of most of the original organic matter is an important one. Recent studies indicate that the effect of stripping is to guarantee a somewhat better quality of water for a few years, but that, in the end, the conditions will be the same as though but little work in this direction had been done. An unstripped reservoir will improve; a stripped reservoir will grow worse until finally, if all other conditions are the same, the quality of water delivered by two such reservoirs will be identical. Even at its very best, stripping is not an absolute guaranty; vegetable growths may occur in any reservoir and can only be guarded against by thorough aeration followed by filtration.

Señores Pablo Solís and Octavio Guzmán* (by letter).—The writers congratulate themselves, as representatives of the State of Puebla, upon the opportunity that now presents itself of knowing, *Señores* So[lís] and Guzmá[n].

* Delegates to the Convention of the American Society of Civil Engineers from the State of Puebla, Mexico. (Discussion translated from the Spanish.)

Flores Solís and Guzmán.

through this meeting of eminent professional men, the present state of the art in the five technical subjects which make up the programme. They regret that this programme lies without the field of professional practice of their State, which is purely textile, and in whose capital, on account of its excellent climatic and topographic conditions, it has not been necessary, up to the present time, to introduce modern sanitary devices. On account of the extraordinary firmness of its soil, it has not been obliged to contend with exceptional foundation problems; and, as the center of an extensive network of railroads which has completely done away with care of the ancient roads, it has not preoccupied itself concerning the future fate of the public highways. The recent growth of automobiling, however, now compels attention to, and interest in, them. On the other hand, our capital being on the eve of establishing a system of drainage and all manner of sanitary improvements, the subject of potable water supplies also greatly interests the State, and, through the writers, it will secure, from the deliberations of this meeting, knowledge of the latest advances in all the important matters proposed for discussion, and the writers will endeavor to co-operate by discussing the two first questions of the programme presented, giving their opinions on these subjects on an abstract basis.

With regard to the first subject under discussion, the writers believe that, with the present state of knowledge and experience in the art of sanitation, only the second alternative stated in the question is practical, that is, to permit a certain amount of contamination, and to rely on a subsequent purification.

In truth the art of sanitation, in spite of the great advance that has been made in the acquisition of knowledge and of practice, has, up to the present time, only undertaken the sanitation of isolated and independent communities. In sanitary matters facts must be considered in their multiple condition, not isolating some with respect to others, because they are never independent. From this point of view it is of little use to attend to the sanitation of one city, if the valley or region in which it lies is not also taken care of, and in the sanitation of any region the disinterested co-operation of the various communities in it is indispensable.

Unfortunately up to the present time each community watches its own interests only, not concerning itself with the interests of the others with which, on account of local conditions, it is inseparably linked, and on whose healthfulness depends in great part its own. If a community does not dispose properly of its refuse, getting rid of it without special treatment of any kind, its final disposition being near neighboring communities, the latter will become contaminated, and disease will be developed in them which may infect the culpable community and even the whole region. Therefore, sanitation to be com-

Señores Solís and Guzmán.

plete and effective must be more than local, it must cover the entire region, and must embrace all towns that are linked by natural conditions; and as long as this desideratum of the sanitary art is not reached, the potable waters in such regions, whatever their origin may be, if they are below the level of the sewage of other towns, will be somewhat contaminated. Even granting great vigilance and control by the Governmental powers, the result will be the same, because unless such regulation is mechanical and automatic, it will be inefficacious. It is fruitless, therefore, to purchase and watch the water-sheds that feed the reservoirs, and, in the opinion of the writers, it is best to allow contamination to take place to a certain degree, trusting to filtration for purification. The question may well be asked: Is regional sanitation which will prevent the contamination of water possible in practice? Judged purely in the abstract, and by the theories of sanitary art only, an affirmative answer forces itself upon us, and, furthermore, that this is the only proper form. It is incomprehensible that any system which restricts its attention to isolated points can be called sanitary. The phenomena of life under whatever form we may consider them, be it individually or collectively, are always the same; and as, in the individual, health cannot exist unless it exists in the whole organism, in the same way, collectively, it will not exist if it does not encompass the whole region. Now, what are the fundamental conditions necessary to regional sanitation, in the strictest conception of the term? The very same conditions as are necessary in individual life, and, summed up, they may be condensed as follows: Continuous renovation; continuous renovation by circulation or motion; and continuous renovation by chemical or substantial transformation. In the life of the individual these conditions in their admirable harmony are regulated by what is known as "the vital principle," and in collective life they are, in turn, regulated by the laws of political economy, and the rights of the individual under the direction of the Government. It is within the field of political economy to arrange financially for the problem of continuous circulation by chemical or substantial transformation, and it is the arduous task of the Government to harmonize sanitary interests in such a way that the best interests of the whole region will be preserved.

In the same degree as these difficulties are overcome, will the art of sanitation advance from being purely local, as it now is, to being regional, as it will be to-morrow, and in that same degree potable waters may be considered as safe from contamination.

In what degree has the scientific disposal of garbage been successfully and economically applied to the sanitation of towns? Much effort has been made in this direction, and results have been obtained, propitious in some cases, adverse in others, but thus far the advantageous results have not been confirmed by properly made esti-

Señores Solís and Guzmán.

mates, and the general opinion among sanitary engineers is that we have not arrived at satisfactory results, especially with respect to sanitation by gravity, in which process the matter being highly dissolved, its extraction is very costly.

Now while the art of sanitation remains in the precarious condition of not being able to get rid of detrimental matter except by the process of solution and removal, the contamination of potable waters is inevitable, and it is necessary to resort to filtration, which is the only solution of the situation in the present state of the art. But when the economical transformation of domestic and other wastes becomes possible, to the extent that it may be applied generally, and when the mental condition, customs, and altruism of the community have advanced to the perfection required by the present state of sanitary science, it will be possible to put its teachings into practice. The decisions of Boards of Health may then be carried out with efficiency, and then regional sanitation may be accomplished, and the non-contamination of potable waters will also be an established fact. In the meantime we must be resigned to allow potable waters to become contaminated, and we must purify them by filtration.

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FOUNDATIONS.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"(*a*) What is the best system of construction for foundations of heavy structures on ground such at that of the City of Mexico, which is an alluvial deposit about 300 ft. in depth, and similar in character to that at New Orleans?

"(*b*) Will iron or steel used in foundations, independently or in combination with other materials, last indefinitely when in direct or indirect contact with water?

"(*c*) Will the strength and durability of concrete in foundations be affected if before setting there is: (1) an excess of water; (2) lack of compression; (3) too rapid desiccation?"

BY MESSRS. LANSING H. BEACH, F. G. JONAH, G. E. P. SMITH, J. C. MEEM, C. M. MORSSEN, PABLO SOLÍS AND OCTAVIO GUZMÁN, AND M. MONEADA.

LANSING H. BEACH,† M. AM. SOC. C. E.—There are a couple of features connected with foundation work in a large city, which were not mentioned in Mr. Fuller's discussion, and which may be new to many members. Maj. Beach.

One point is, that it may be advisable to avoid the use of steel as far as possible on account of the danger of electrolysis. It does not follow that steel construction under ground will be safe because there is no danger at the time the foundation is laid. The use of electricity is constantly increasing, and it is a reasonable supposition that with the installation of new power plants, especially those operating under

* Continued from August, 1907, *Proceedings*.

† Major, Corps of Engineers, U. S. A.

Maj. Beach. a high voltage, and the deterioration of street car lines, there will be in future a greater quantity of electricity flowing through the ground than at present. A small amount of electricity traversing the steel of a foundation for several years, or a larger amount for a shorter period, must affect the strength of the combination. Such conditions do not obtain in the country, but there is an existing and increasing danger to the steel in foundations in every large city from this cause.

The other point is that in a city, where a building is apt to go to the property line, the engineer often does not have room to construct a foundation of such character as that which he would usually adopt for a structure occupying but a portion of the land owned. If the structure is on a line of railroad, or standing by itself, the engineer can easily extend the footings so as to obtain the required bearing limit, or he can often without difficulty compress the soil to the necessary degree. In a large city where the property lines are accurately marked and must not be crossed, and the owner desires to cover every inch of ground upon which he is entitled to build, there is no such thing as spreading the footings, nor is it always practicable to compress the soil without producing such a lateral movement as will affect adjacent buildings.

A man may desire to erect a building of a certain weight per square foot on his lot, and the engineer can devise a foundation which will produce stability in that structure, but in soft soil the adjacent buildings, if much lighter, may be lifted, bulged, or cracked, which may result in a lawsuit and perhaps further expense. In a large city with a yielding soil a man cannot build unto himself alone; his neighbors must be taken into account, and it often takes more time and money to avoid injuring them, than it does to provide for his own.

In a compressible soil containing a large quantity of ground water, there is great danger from the subsequent draining away of that water. It helps to sustain the load, and foundations which have stood and served their purpose for more than a generation, may fail completely upon its removal and the consequent compacting of the soil. The speaker knows of a building, which had stood perfectly for many years, and which has been completely destroyed in this manner.

Taking all things into consideration, it is believed that the engineers and architects of Mexico City have as difficult foundation problems to solve as are presented anywhere to-day.

Mr. Jonah. F. G. Jonah, M. Am. Soc. C. E.—Foundations for all heavy structures in New Orleans are now made of piling. This is the best foundation for that locality because, in the absence of bedrock or hardpan, piles give sufficient frictional resistance to sustain all necessary loads.

The soil of New Orleans is nearly always pure alluvium many hundreds of feet deep. There is, in various parts of the city, an

underlying stratum of shells and beach sand, usually 40 ft. below the surface and from 6 to 8 ft. thick. Piles can be driven through this, but it is not considered necessary to do so, and they are stopped in this stratum. This material was encountered in driving the foundation piles for the new passenger station now being built at Canal and Basin Streets, and in the foundations for the Hagan Avenue Bridge, 1 mile away, while, just below the city limits, where the new Frisco Docks are being constructed, and where more than 36 000 piles have been driven, alluvium was the only material reached. The same condition obtains on the work of the new Sugar Refinery, also just below the city limits, where more than 6 000 piles have been driven. On the dock work, which is under the writer's charge, 75-ft. piles have been driven in trenches excavated 15 ft. below the surface, so that for 90 ft., at least, there is nothing but pure silt. Careful records and experiments show that in this material a 60-ft. pile will sustain a load of 65 tons without settlement, although 16 tons per pile is the average load calculated. While these piles may be driven very quickly—as much as 4 in. per blow—it is often found that, if they stand partly driven over night, on resuming work next morning several blows are necessary to start them. Mr. Jonah.

The writer has also noticed, in driving piles for trestles in New Orleans and vicinity, that while a pile might go as much as 1 ft. at the last blow, yet by the time the deck and track were on, the trestle would stand up under ordinary traffic.

The piles used are pine sticks, cut in Louisiana and Mississippi; they are very straight and smooth, will average about 60 ft. in length, 6 in. in diameter at the small end and 13 in. in diameter at the butt, and are now furnished and driven for from 30 to 35 cents per linear foot.

The occurrence of the sand and shell stratum in patches can be accounted for on the assumption that it formed part of the old coast line or probably formed small islands which were gradually connected with the mainland and covered by the upbuilding of the Mississippi Delta.

The great holding power of piles in this silt is due to the free lateral movement of the soil causing the pile to be firmly gripped as soon as driven. The extraordinary lateral movement of this soil, and facts relating to its depth and subsidence are referred to in the discussion by E. L. Corthell, M. Am. Soc. C. E., on the paper entitled "The Reclamation of River Deltas and Salt Marshes."*

In driving piles in this material some care must be exercised in their spacing, as it is possible to drive them too close to one another, in which case the frictional resistance would be measured

* *Transactions*, Am. Soc. C. E., Vol. LIV, p. 88.

Mr. Jonah. by the circumference of the cluster rather than by the circumference of the piles separately—3½ ft. is a fair average spacing.

This foundation is undoubtedly the best for New Orleans as the piles go below the level of basements, sewers and canals; and modern buildings are being erected on such foundations without any settlement. The foundations will also be permanent, as wood, in soil of this character, when carried below the line of atmospheric and moisture changes, lasts indefinitely. This has been abundantly proven in New Orleans where, in boring for wells, logs in good preservation have been encountered hundreds of feet below the surface. Recently, in excavating for the basement of the new passenger station at Canal and Basin Streets, perfectly sound cypress trees were uncovered 12 ft. below the level of Canal Street.

Excavations frequently expose old foundations on cypress footings in as good condition as when put in a century ago. These footings are usually from 4 to 6 ft. below the surface.

The drainage works of the city, now in course of construction, will probably lower the water level to 8 ft. below the surface, so that in the future timber foundations may not last as well as they have in the past, unless carried below that level, which of course, is the case with pile foundations for new structures which are provided with basements.

As to Mexico City, the writer has observed that the soil is not similar to that of New Orleans, for there is no underlying hard stratum; the hard stratum is on the surface, and is a material known locally as "tepetate," something like hardpan, overlying a great deposit of volcanic ash. With the drainage of Lake Texcoco, and the consequent lowering of the water level in the city, the surface soil is settling and carrying with it the buildings, and as the settlement is not uniform, many structures are being cracked.

The speaker believes that piles would be the best foundations in the City of Mexico; but, as the cost of timber would be excessive, the situation could be met with concrete piles. There might be some difficulty in putting down concrete piles of as great a length as the timber used in New Orleans, but a shorter pile, of greater circumference and with a greater taper, would undoubtedly answer, if it went below the water level and well below the level of excavations for basements and sewers.

As to the strength and durability of concrete being affected by an excess of water and lack of compression, this is one of the questions upon which the Engineering Profession has changed ground in the past fifteen or twenty years. Formerly, all specifications stated very definitely that an excess of water must be avoided; they contained the clause, "just sufficient to flush to the surface when thoroughly tamped," etc., etc., or, in other words, dry concrete was

almost always used. To-day the reverse is the case, as wet concrete —decidedly wet—is the rule. The speaker believes that no material injury arises from the use of a wet mixture, provided the forms are tight and do not permit the mortar or cement solution to leak out. This is a change brought about very largely by the contractors of the country. Where impervious concrete is required, the wet mixture will give the best results; also, in filling irregular forms with concrete the wet mixture will fill angles and corners in which it would be very difficult to tamp a dry mixture; consequently it gives the average job a much better appearance when the forms are removed. Mr. Jonah.

G. E. P. Smith, M. Am. Soc. C. E.—In relation to the effect of rapid desiccation on concrete, the speaker's experience has been gained in a country where for days the temperature stands above 100° and the humidity below 10 degrees. On one occasion the local weather observer, interpolating outside the Weather Bureau tables, unwittingly reported the relative humidity as a negative quantity. The ground also becomes intensely dry, as there are often periods of from 5 to 10 months in which there is no rainfall to counteract the surface evaporation. Concrete work, however, is carried on throughout such seasons without interruption, and most contractors take no further precautions than are taken in humid climates. Mr. Smith.

Under such conditions, the effects of "too rapid desiccation" must be extremely severe, and if engineering structures are endangered from this cause the fact would be readily apparent.

One of the severest tests of concrete is in sidewalk construction, and some utter failures have been recorded. In one instance 13 miles of newly-laid sidewalk were taken up at once; and 3 miles of sidewalk laid this year are disintegrated to such an extent that they will be removed and replaced this summer; however, many more miles have been well built, and after years of service are in perfect condition without cracks or worn holes. Consequently, concrete sidewalks are still the most popular, and, from the municipal standpoint, the most satisfactory type in the arid region, which includes the Southwestern States, together with the northern half of Mexico.

It is found that certain brands of cement which are satisfactory for tunnel and heavy foundation work are positive failures when used for sidewalks. The rapid desiccation of the latter must, in part, account for this difference. On the other hand, most brands of cement do not suffer in this way. Concrete, for sidewalks and for other purposes, is usually mixed and laid, and sets in the ever-burning sunlight. After some hours, and when thoroughly set, it is covered with dirt or boards and wetted, and usually comes out in good condition.

Mr. Smith. As soon as set takes place, further desiccation can usually be prevented. In making cement pipe the speaker has kept the concrete wet for a week, but bridge piers are sometimes finished in midsummer with little or no sprinkling.

Where freshly-laid concrete is to be exposed to rapid desiccation a cement should be selected which is known to withstand such conditions. The defects of high-limed and uncured cements are probably accentuated by desiccation. A suitable cement, however, will withstand almost any conditions met in practice, and concrete work in the arid region is not limited by this obstacle.

Incidentally, it may be added that the aggregate used in Tucson, Ariz., is a basaltic lava, identical in composition and structure with that of Tlalpam, near the City of Mexico. This lava rock is also used for macadamizing the streets, and forms a well-bound surface without the aid of a roller.

Mr. Meem. J. C. Meem, M. Am. Soc. C. E. (by letter).—Referring to the question of concrete in foundations being too wet or drying too rapidly, or the necessity for ramming, the results of some recent observations of actual conditions will be given.

In underpinning the buildings along the line of the Rapid Transit Subway in Brooklyn, it was sometimes necessary to go to a depth of 40 ft. below the curb line, the lower 4 ft. being sand below the level of mean high water. The method pursued in all cases was to cut out sufficient brickwork on each side of the pier to be underpinned just above the floor level and insert needle-beams (generally 20-in. 80-lb. I-beams, 18 ft. long) in sufficient numbers to carry the load. These were wedged up from a cross-blocking of heavy timbers, and cross-needle-beams were set into recesses cut in the piers, a middle beam being put through a hole cut in the pier when necessary. These beams were cemented and wedged to an absolute bearing, and were then grouted in so as to form practically a component part of the pier.

An excavation, about 8 by 8 ft. square, was then made under the foundation to a depth of about 4 ft., and supporting chains were inserted to carry the hanging portion of the foundation. A 6 by 6-ft. pit was then box-sheeted, that is, horizontal sheeting was used and set in by the well-digger's method. Cement was used in the back of the sheeting to insure filling all spaces, and holding the upper strata of loose sand in place. As soon as water level was reached, interlocking steel sheet-piling, about 5 ft. 6 in. long, was set up inside the pit in a 5 by 5-ft. square and driven down till its top was within 6 in. of the water level; then, without pumping, the sand was cleaned out to a depth of 4½ ft. and concrete was deposited through a chute until the pit was filled to about 1 ft. above the water line. Dowels of boulders or rods were left projecting

CONCRETE PIERS, SHOWING FACE AT THE OVERHANG.

from this in order to give a bond for the upper portion of the pier. As soon as the concrete had partially set, the remainder of the pier was filled in to within about 4 in. of the foundation level. After setting, this was grouted in with semi-liquid mortar, care being taken to fill every possible void by ramming and packing the grout well under the foundation. After about 5 days the beams were removed, a few at a time, and the holes in the brickwork were replaced with new masonry. Mr. Meem.

Plate LXXXVIII shows the face of two of the concrete piers at the overhang, where the 8 by 8-ft. space above the 6 by 6-ft. pit was filled in. The face shown is that left by the original boards used for the sheeting, and gives a fair idea of the satisfactory texture of the concrete. This concrete was made under the Rapid Transit Commissioners' specifications, and was composed of a 1 : 3 : 4 mixture of cement, sand, and gravel, the latter ranging from $\frac{3}{4}$-in. to $1\frac{1}{2}$-in. stone.

The deductions, from observations covering a large number of these piers, are:

(1) Concrete does not have to be rammed if put in sufficiently wet.

(2) In foundations, it is practically impossible, within the limits of common sense, to put in concrete too wet, always providing, of course, that the water is not allowed to run away.

(3) When concrete as wet as practicable is placed in foundations there is no danger of too rapid desiccation.

The writer believes that it is established beyond controversy that concrete should always be protected from drying out too rapidly, and when it is put in place very wet there is no need of protection, except where it is exposed to the direct rays of the sun in hot weather.

C. M. Morssen, Assoc. M. Am. Soc. C. E. (by letter).—The following is a brief description of three systems of foundations used by the writer with good results: Mr. Morssen.

Foundations by Reinforced Concrete Coffer-Dams.—A coffer-dam, 30 by 12 ft. in section, and 15 ft. high, was built above the ground, in which it was to settle down. The water was taken out by a centrifugal pump, which removed 2 cu. yd. per min. This pump was driven by an electric motor erected on top of the coffer-dam. The dam was lowered by excavating inside of it, the vibration of the motor in the coffer-dam proving of great assistance in working it down. The advantages of this system are:

1st.—A coffer-dam, of the proper dimensions and of the same height as the depth to which it is to be sunk, can generally be built above the ground. The motor,

Mr. Morssen.

pump, and suction pipe being fixed on top of the structure, and the suction pipe being of a definite length, the work may be carried on steadily, as no cessation is necessary from time to time to lengthen the pipe, as is the case with other systems.

2d.—Absolute safety for the workmen.

3d.—The motor's vibrations, combined with the great weight of the coffer-dam, ensure a regular settling of the dam.

4th.—The walls of the coffer-dam, being reinforced, act as very strong beams, and, when big stones, wooden timbers, or pipes, are encountered, an aperture can be made under the wall of the dam without injuring it, thus permitting the removal of the obstruction. After the dam has been sunk to the required depth it is filled with concrete, and thus forms a very solid foundation.

The general arrangements are shown in Fig. 1.

Foundations by Reinforced Concrete Piles.—Reinforced concrete piles may be used in soils of weak but uniform character. Such piles are cast in vertical or horizontal moulds, and, after the concrete has set (in from 6 to 8 weeks), may be driven in the same manner as ordinary wooden piles. The precaution must be taken, however, to protect the head of the pile from the blows of the hammer by a special helmet. Each pile is reinforced by from four to eight round iron rods, and iron shoes are fixed on the bottom of the pile. Good results are obtained by driving with a very heavy hammer, falling a short distance, and giving a large number of blows per minute. For the foundations of some bridges built in Europe the writer has driven piles 50 ft. long and 16 in. square, and the results were much better than were anticipated.

Reinforced concrete piles have been used extensively for foundations in London, England, as there wooden piles are soon destroyed by worms.

As the friction between soil and concrete is of great numerical value, in many instances the piles need not be carried down to solid ground. Further, as reinforced concrete piles cannot be destroyed by insects or external causes, they provide a reliable foundation in such cases. One of these piles, 50 ft. long, driven in a middling soft bottom, requires from 4 000 to 5 000 blows, but, by using water under pressure, the pile can be driven home more quickly. The water can be conveyed by an iron pipe embedded in the concrete, or by simply leaving a hole in the center of the pile. By using water under pressure, from twelve to fifteen piles, from 40 to 50 ft. in length, can be driven in a day by one driving ma-

THE COMPRESSOL PILLAR AS IT APPEARS IN THE SOIL.

chine. The cost of these piles depends largely on the number required (as the initial installation is very expensive), and varies from $1.50 to $5.00 per lin. ft. of pile driven, the greater the number of piles the less the cost per foot. Mr. Morssen.

The driving of reinforced concrete piles shows in a marked manner the great adhesiveness of concrete and steel, as the pile,

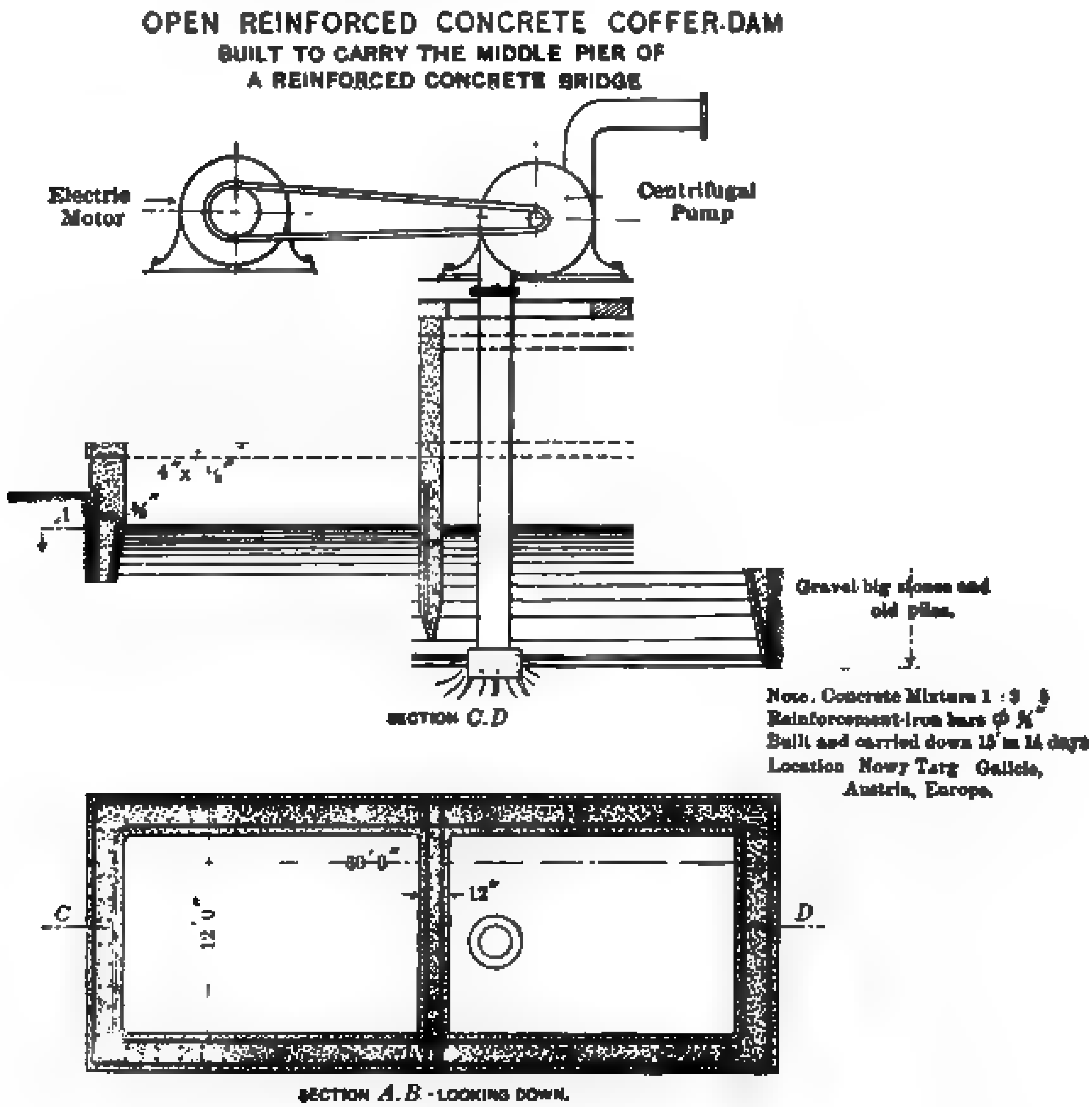


FIG. 1.

before it is completely driven, has to stand very heavy blows and much vibration, and the endurance of the combination speaks well for reinforced structures as a whole.

This process is illustrated by Fig. 2.

Foundations by the So-called "Compressol" System.—The idea of this system is to make a hole in the ground by lateral and verti-

Mr. Morssen. cal compression of the soil, the cavity thus made being afterward filled with concrete. A specially designed pile-driver lifts what is styled a "perforating rammer," of conical shape, weighing from 2 to 3 tons. This rammer is dropped from a height of from 25 to 30 ft., and its fall compresses the soil laterally and vertically, until in a short time a hole is formed in the ground. The hole can be carried to the required depth by dropping the hammer repeatedly. Owing to the great weight of the hammer and the height from which it is dropped, the soil is closely compressed, and temporarily rendered water-tight. In cases where the soil is too soft to give a close hard surface a certain amount of lime may be added during the perforation. This lime is firmly compressed against the sides of the hole, rendering them water-tight for the period necessary to place the concrete.

When the cavity has been made of the desired size, it is filled with concrete which is tamped down with a rammer of a special shape. Owing to the thorough tamping, the concrete spreads in the hole and forms a very strong pile.

In many instances the volume of concrete required is four or five times larger than the hole itself, as the ramming of the concrete causes it to expand in every direction. This expansion further strengthens the foundation by the additional compression of the soil.

The method of forming the columns is indicated in Fig. 3.

The chief advantages of the "Compressol" system are:

1st.—It gives absolute safety, by enabling pillars to be built of the desired bearing capacity.

2d.—No excavations which weaken the soil are necessary; on the contrary, the soil is strengthened by compression.

3d.—It obviates all danger to which laborers working below the surface of the ground are subject.

4th.—All operations are done mechanically.

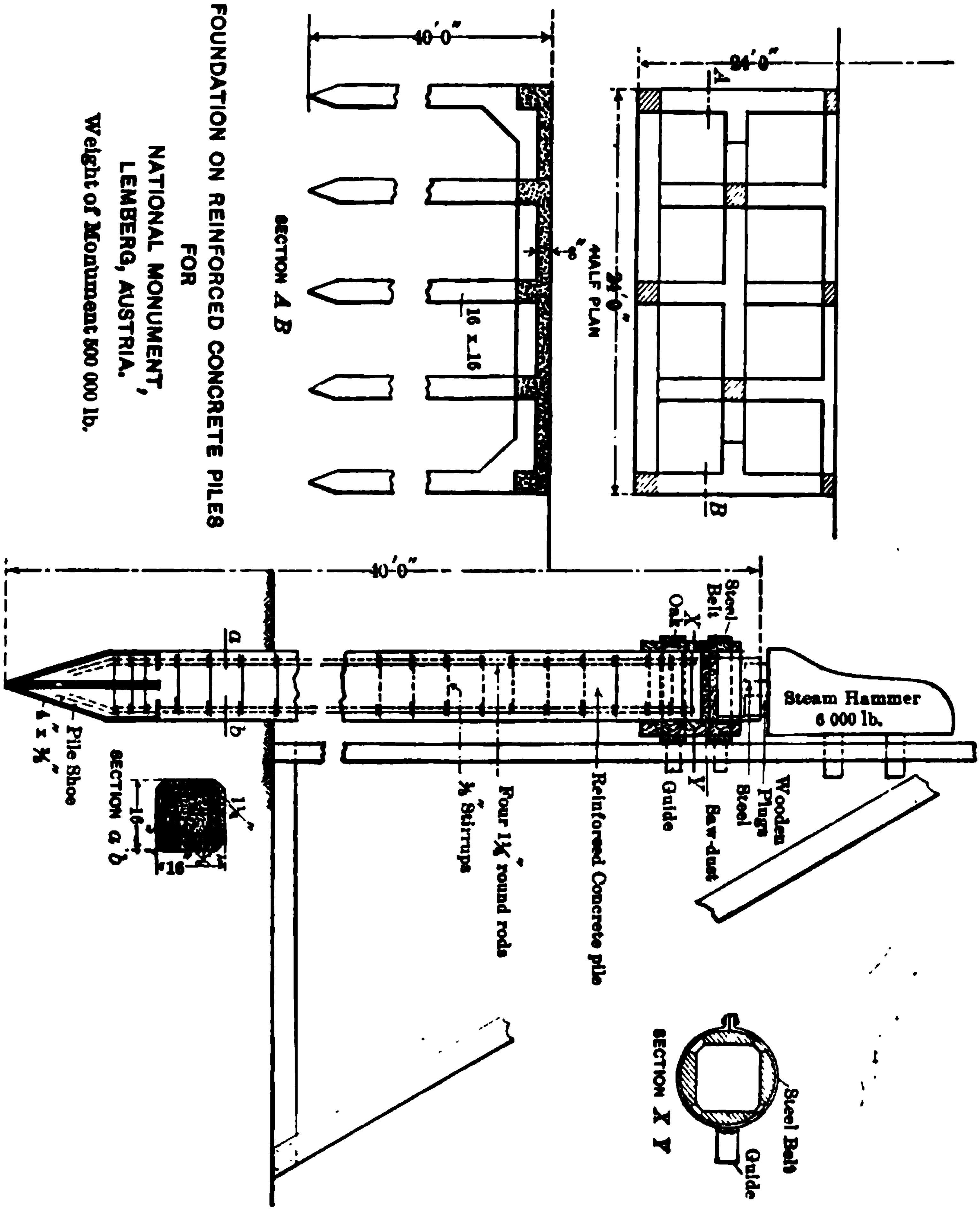
5th.—It is a rapid method—a pillar from 25 to 30 ft. deep can be filled in from 3 to 4 hours.

6th.—The concrete, tamped down with very heavy rammers, percolates every weakened part of the soil, and gives it the required strength.

The "Compressol" system has been used in numerous cases and in many kinds of soil, and has given very good results. It has been used for the foundations of many bridges and buildings in France, Germany, and Egypt.

The cost of a pillar having a carrying capacity of from 90 to 100 tons is from $35 to $55.

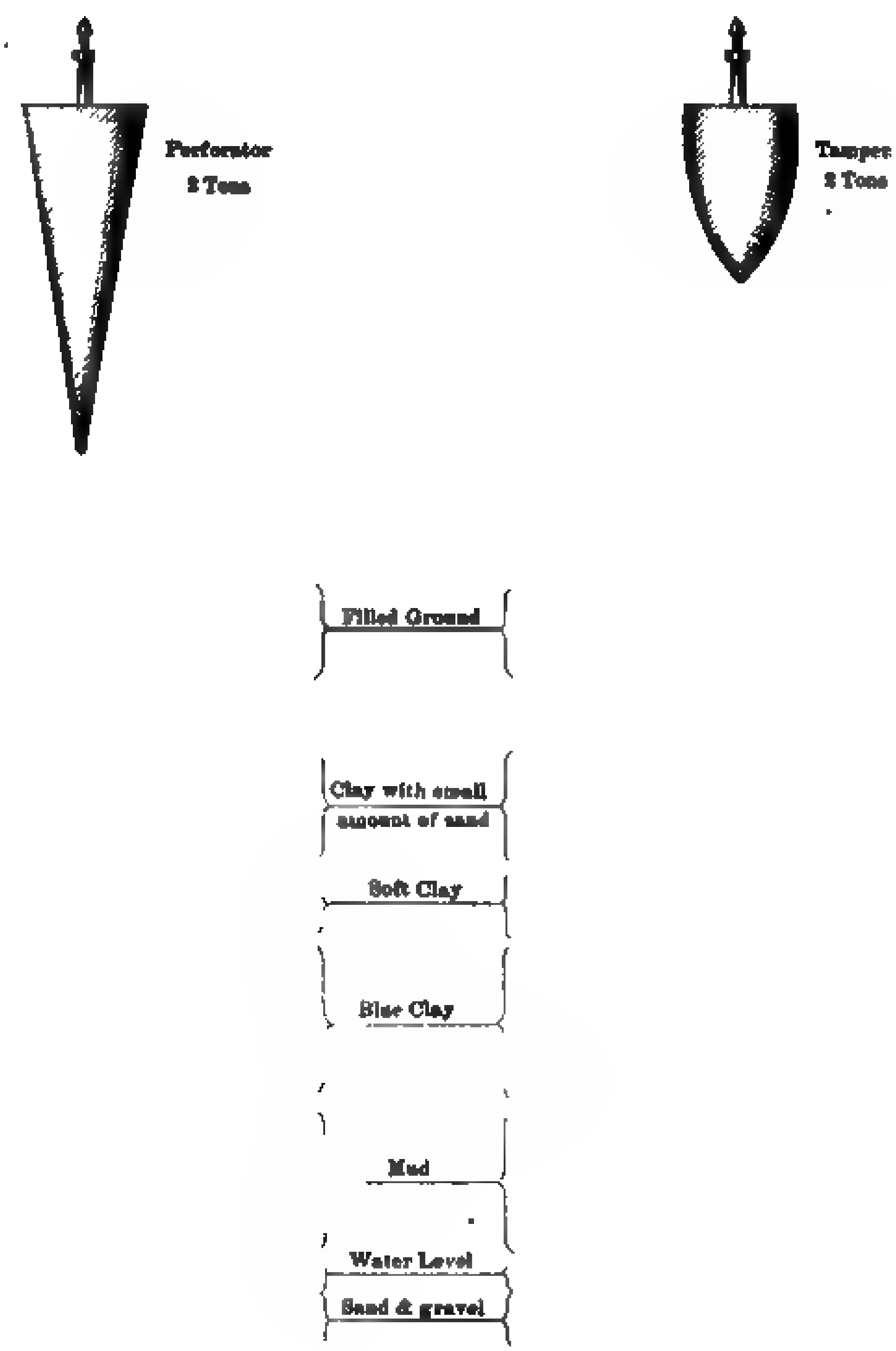
Mr. Morssen.



FOUNDATION ON REINFORCED CONCRETE PILES
FOR
NATIONAL MONUMENT,
LEMBERG, AUSTRIA.
Weight of Monument 500 000 lb.

Fig. 2.

Mr. Morssen.



TAMPING AND FILLING

FIG. 3.

Mr. Morssen

In conclusion it may be stated that either of the three systems described herein may be used in any ground under heavy structures, and it is the writer's belief that such foundations would give good results in such ground as that of the City of Mexico.

It is impossible to assert that any foundation will last indefinitely, yet iron or steel embedded in a rich concrete mortar will remain in perfect preservation as long as the concrete itself exists. The durability of concrete is fully proven by the Roman remains in that material which are unearthed from time to time.

As a practical illustration of the durability of iron and concrete when in contact with water, the case of a concrete wharf at Grenoble, France, may be quoted. This wharf, after having been in existence for about 80 years, was pulled down, and many iron tools, nails, and anchors were found accidentally embedded in the concrete, and all were in good condition. On the other hand, iron used independently, for foundations affected by water, soon rusts; and its entire destruction is merely a matter of time.

The writer can state definitely that an excess of water does not affect the strength and durability of concrete foundations, if the water to which such foundations are exposed is at rest or quite motionless while the concrete is setting.

The strength of concrete is affected seriously by lack of compression when it is put in dry, as its value depends on its density, and, unless thorough compression or tamping takes place, the body will be "spongy" and not fit for its purpose.

If, during setting, the desiccation is too rapid, the shrinkage or contraction consequent thereon will cause cracks to occur in the concrete, which, of course, will affect its strength seriously.

Señores Solís and Guzmán

Señores PABLO SOLÍS and OCTAVIO GUZMÁN* (by letter).—This theme belongs to the Engineers of the City of Mexico and New Orleans, and, as specialists upon the subject in question, it is hoped they will place their opinions before this Society. By their experience, which has been recorded in special articles, we have been informed, that in soils of this nature, foundations of masonry are inefficient, because they yield and sink; that piling has not given good results, as may be seen by the bad condition of the ancient buildings of Mexico with this type of foundation; and, also, because this soil is so indefinitely compressible that a final settlement of the piles is never obtained. It may be observed that piles sunk to the limit of "the rebound of the hammer," continue to sink when, within a short time, they are subjected to further driving from the same hammer. We have also been informed that the practice of deep foundations is not good, because it does not diminish the settlement and necessitates laborious drainage,

* Delegates to the Convention of the American Society of Civil Engineers from the State of Puebla, Mexico. (Discussion translated from the Spanish.)

Señores Solis and Guzmán. and that, on account of the currents produced in the subsoil by such drainage, these excavations are the cause of the cracking of many of the old buildings nearby; that foundations with sand have been successful in the construction of the Teatro Nacional; and that experience shows that the best construction for Mexico is the grating form, whether a grate or platform of wood or iron is used, or a monolithic plate of "beton" or equivalent material. This process it is understood gives good results, because, by means of it, the following requisites which are indispensable for a good foundation in Mexico are obtained:

(1).—The distribution of the total weight over the largest possible area so as to diminish as much as possible the intensity of the load.

(2).—The shallowness of the foundation which avoids laborious drainage, which drainage causes internal currents resulting in damage to contiguous buildings.

(3).—The distribution of the load, so that its intensity will be the same at all points, if the ground is homogeneous and uniformly compressible throughout; and, if not, then the distribution of the load proportionately, so that its intensity does not exceed the reaction of the ground at any point. Finally it should be noticed that the builders of this capital, upon whose authority these observations are based, fix ½ kg. per sq. cm. as a safe load limit for foundations, and as a maximum load, which should be exceeded only in very special cases, 1 kg. per sq. cm., figures that represent the reaction of these soils.

The preceding facts give the essence of the usual practice in foundation construction upon the soils of Mexico City. Said facts or figures would give of themselves an adequate answer to the first part of the question under discussion, were it not that they refer exclusively to the condition of the subsoil of this city prior to the construction of the drainage and sewerage systems. Since these improvements, however, the quality of the subsoil has changed, and, therefore, as the data have changed, the process of foundation building must change. To what extent and in what manner practice in foundation work will be modified is not known, and the writers have many doubts which may be formulated in the following questions: What changes have been wrought in the subsoil by the drainage of the city? Has the modulus of ground reaction changed? To what depth has the water level dropped? And, if it has dropped but little, should present foundations for this capital go down to "water-saturated ground," or should we build them superficially in the desiccated strata?

With respect to the last question, the writers believe that foundations should be built upon the surface of the diluted soil, for there the ground being semi-fluid, the water, on account of its incompressibility, acts as a powerful medium of reaction against the weight of buildings, and, to a certain extent, in accordance with the principle of Archimedes that a submerged body loses a part of its weight equal to the

Señores Solis and Guzmán.

weight of the water displaced by it. From this point of view it may be considered that foundations upon gratings in soils as saturated with water as these in question, owe their efficacy against sinkage of the load they carry to the fact that they are, we might say, floating. The ancient buildings of this city built upon gratings are still in excellent condition. On this account also, modern construction companies are justified in constructing in the City of Mexico foundations with huge gratings of steel, iron and beton, and are also justified on account of the changes in the subsoil since the drainage in extending foundations to cover not only the base of the wall, but the whole area of the building, as has been done recently in the magnificent building for the Messrs. Boker.

In closing, the writers will refer to the last part of the topic under discussion: "Will iron or steel used in foundations, independently or in combination with other materials, last indefinitely when in direct or indirect contact with water?"

As mixed foundations of this nature are of very recent installation, it is not possible to find history concerning them that might be useful in passing judgment upon this subject. On the other hand general and numismatic archæology might contribute some data, especially the latter, as for instance in the case of Chinese iron coins, now found in museums, and which may have been for many years under water.

With respect to iron in salt water, it is known that, in the Harbor of Vigo, when the treasure was taken from some American galleons which had been sunk in Colonial times in that harbor, iron cannon were found with that treasure, the metal of which was extraordinarily altered and softened to the consistency of wax. We also have knowledge of the iron taken from the breakwater at Brest, which had been immersed for a century and was found half destroyed, the material, as attested by M. Lidy, Civil Engineer, containing hardly 56% of free iron, the remaining portion being in very bad condition, with the internal fibers almost destroyed, showing many eaten out spots. Both these cases, however, should be discarded, because the destructive effects were due to marine salts.

With regard to fresh water, we have no knowledge of data that would show how iron behaves after an indefinite period of immersion; the iron of hydraulic wheels, canal gates, and many other objects used in the industries, permanently immersed, apparently remains well preserved when subject to the continuous or, at least, to the frequent flow of water. In these cases deterioration due to wear by friction of water is greater than that due to oxidation, and, as the renewal of parts happens slowly, and original shapes are always retained, the illusion of the immortality of the metal is produced, which in reality is only perpetuity of form. In still waters oxidation is more rapid,

Señores Solís and Guzmán.

but it reaches the interior of the metal very slowly, the first coating of oxidation formed, becomes a protecting coat against the propagation of this deterioration, and a condition of permanent equilibrium and preservation seems to become established. Iron buried in foundations invaded by water is subject to these conditions exactly, and as the mass of the foundation is strongly compressed, the lack of air renewal is complete, the temperature low and uniform, and the oxidizing forces are paralyzed. It is probable that iron in foundations, under these conditions, if it is not indefinitely preserved, at least its deterioration must take place very slowly; and as this deterioration consists in the chemical change of one body into another, the result, under the constant powerful action of the weight of the building, can only cause, in its turn, a very gradual settlement of the foundation, until, by necessity, a final settlement is reached. This will be the result even though the mass of iron is finally changed to a mass of oxide of iron, since it is probable that, on account of the constant pressure to which it is subjected, hollows could not be left in the mass.

On the other hand, the spirit of the present epoch is not as conservative as that of the past, and does not occupy itself with the indefinite conservation of things, because we know better than those before could have known, that the exigencies of progress, in its continuous necessity for new adaptations, demand less durability in modern processes. In reality, the formidable hardness of ancient structures, on account of the great labor of pulling them down, was more of a bane than a benefit to those who came after, as well as a profit to the industry of explosives.

Besides, studying the subject from the point of view of preservation, there is nothing disquieting, the remedy for which is not within the reach of modern science. If iron should not keep well in water, recourse to a covering of cement will preserve it.

Since reinforced concrete has come into general use, it has been noticed that iron remains unaltered in cement. After years the metal shows no vestige of oxidation, and preserves the bluish tint that it has when fresh from the milling machine, and there is no reason to believe that this preservation should not be indefinite, even in the case of submerged structures. The protection of cement must by force augment with time, as masonry of cement continues taking from the air or water new powers of durability and resistance.

Can there be a doubt of the practicability of preserving iron indefinitely under any circumstances, since Nature has shown us its numerous resources in the case of the preservation, in the ruins of Pompeii, deep under a layer of ashes, fresh and intact for many centuries, not only the unstable human organism, but even the transient and fleeting expressions of the anguish of death preserved upon the faces of those there buried?

Señores Solis and Guzmán.

In conclusion, the writers present the following summary of their views upon this subject:

First.—There is no practical experience as to the indefinite preservation of iron in water.

Second.—By reasoning, it seems evident that iron will be preserved in the water of foundations without special preparation.

Third.—There seems no reason for worry about an indefinite preservation of this material. It need only be preserved within time limits which are governed by the growing necessities of readaptation by modern progress.

Fourth.—That if it were deemed advisable to preserve iron indefinitely in foundations, it is possible to do this by having recourse to science.

The abstruse plane in which, almost exclusively, the writers have taken up this discussion, on account of their small personal experience, is as fertile in wise conclusions as is the field of experiment and the elucidating figures of statistics; the process used, therefore, is, due to lack of others, as good as any. If the derived conclusions lead to error, the writers will listen with pleasure to any remarks and objections, and honestly bear the full weight of their errors.

Señor Moneada.

Señor M. Moneada (by letter).*—The lowest ravine of the valley of Mexico must have been at some time filled with rocky promontories, like Chapultepec, Peñon de los Baños, Peñon Viejo, Flahna, etc., which projected above the waters of the lake or above the flatlands. The stratum of alluvial deposits which was subsequently formed is on this account of varying depth, and when it became dry land there remained a soil of light consistency seated upon water. The Spaniards when constructing heavy buildings resorted to the old and excellent system of piling, which gave good results in some cases and bad in others, as, for instance, the Church of Loreto, and the Mineria.

The writer believes that these varying results were due to the difference in depth of the semi-solid and compressible strata forming the surface. This theory would explain the uneven sinking of the Mineria, taking for granted that at the northern and southern sides, where it has sunk least, there exists a rocky subsoil at a lesser depth than at the eastern and western sides.

The trouble due to the slight and uneven solidity of the ground in that epoch was considerably increased by the drainage of the valley, for as the level of the lake waters fell, the waters with which the soil was saturated fell also, and a porous and more compressible soil resulted. It is desirable, therefore, to solidify the soil evenly and sufficiently at the least expense. It is very expensive to make deep excavations and fill them with I-beams and cement, and, in some cases, useless, for, although on account of its rigidity this heavy platform

* Translated from the Spanish.

Señor Moncada. will not rupture, it might move into an inclined position upon its foundation of uneven resistance, and the building upon it be thrown out of plumb.

It might be well to take the following steps:

(1).—Examine the nature of the soil upon which the building is to be erected by means of artesian well borings of not more than 30 m.

(2).—Drive piles varying in length and number, according to the comparative weakness of each part. The displacement by driving the piles will cause lateral compression, and the soil will become more solid. These piles are indestructible, as has been proved by those which were driven many years ago and are still in good condition, but even if time should destroy them, the ground would retain its vertical resistance, and in this way the firmness of the soil would be equalized as much as possible.

(3).—Upon these piles the platform could be constructed of a minimum thickness, sufficient only for solidity.

(4).—Upon this platform, which would be 2 or 3 m. below the street surface, the walls could be built, but built broader at the base than at the street level. In this way the desired strength would be obtained, and useless filling between contiguous walls would be avoided.

(5).—All back-filling would be done with the earth from the excavation, and the cement or hydraulic lime of the walls thus covered would harden more after setting.

Upon a foundation of this nature, steel buildings with stone "coating," or lighter and cheaper reinforced concrete buildings, may be built.

A structure built upon a platform that has settled unevenly might perhaps be straightened, though with difficulty, and to do this a trench of convenient width and depth should be opened on each side of the parts which have not settled. The weight of the building would then force the earth under those parts to slide to the bottom of the trench, all lateral pressure being removed, and the building would plumb itself. It would be necessary, however, to study many problems of resistance to obtain good results.

The writer believes that iron buried in foundations and protected with mortar will keep indefinitely, for there is no constantly renewed supply of oxygen, as is the case in water and still more in air.

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PAVEMENTS.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"Will the paving materials of the present be used in the construction of the pavements of the future?"

By Messrs. Horace Andrews, Gardner S. Williams, Lansing H. Beach, E. M. T. Ryder, William H. Lawton, Philip W. Henry, and B. Bienenfeld.

Horace Andrews, M. Am. Soc. C. E.—The subject as announced seems rather vague. Judging from the opening paper and discussions, the question might have been altered so as to read: "In what manner will present paving methods be changed in the future, and what materials will be used?" As almost all possible materials have been used, up to the present time, it is pretty safe to say that the materials of the future will comprise those that have been used in the past. Mr. Andrews

Paving materials may be divided into two classes: inorganic, such as stone or brick; and organic (those containing carbon in chemical combination), such as asphalt and wood. The latter class is more unstable than the former, and is liable to depreciation and decay from causes which have no marked effect upon inorganic materials.

At present, under certain conditions, the organic pavements seem to give good satisfaction and to withstand the trying impact of the iron-clad hoofs of horses with little wear and with a minimum of noise. The observations of the speaker within the last few weeks indicate that in the cold climates of our northern cities, Buffalo, Montreal, Albany and New York City, asphalt is disintegrating from causes

*Continued from August, 1907, *Proceedings*.

Mr. Andrews. other than heavy traffic or the abuse of cuts for trenches. A chemical change, or some loss of volatile constituents, seems to be responsible for these depreciations, which are widespread to an alarming extent. Perhaps this breaking up of the asphalt is due to great changes of temperature; at all events, it is not noticeable in the City of Mexico, nor has it been observed by the speaker in Washington.

If chemists can ascertain the exact treatment necessary and the precise kind and quantity of asphalt needed for any given climate and combination of sand or broken stone, so that present uncertainties may be avoided, the continued use of asphalt will be better assured.

Asphalt blocks laid with the smallest dimension vertical, or as horizontal slabs, so as to simulate sheet asphalt, do not seem to be a successful innovation. A pavement so laid is going to pieces very rapidly in the City of Albany. Perhaps it is the well-known tendency of a slab to rock and move under traffic that facilitates its destruction, especially where cold causes shrinkage, opening of joints and brittleness of the asphaltic mixture.

The speaker has given some thought to the effect upon the condition of a pavement, which is due to covering the soil with a waterproof roof of pavement, thus lessening its normal supply of water from rains. Sometimes the sidewalks are also nearly water-proof, and then the water contained in the soil's interstices can only be drawn from below, and in lesser amount, by capillary attraction. It is reasonable to suppose that the normal proportion of water is reduced by a waterproof covering, and that a shrinkage of the subsoil beneath the pavement may then occur. The speaker has observed a settlement and cracking of impermeable pavement which replaced cobblestones, where the subsoil was a pure clay. Such settlement is difficult to explain under any other hypothesis than that mentioned.

A secondary question arises: "Will the traffic of the future be of the same nature as that of the present?" Within a few years there has been a rapid increase in the use of motor vehicles and the adoption of elastic tires. At present these do not materially affect traffic conditions, for horses are as numerous as ever, but who can say that this use of horses will not cease at some future day? In that case many alterations in paving methods may ensue. Already strips of brick pavement in macadam roads are proposed, in order to avoid the raveling of the latter by automobiles. Such a combination is now being adopted on one avenue in Albany.

The advisability of the comparison of the wear of pavements by some scientific process involving a census of traffic is obvious; but in taking such a census, the personal equation may be large. The observer must guess at the weights of the contents of many loaded wagons, and his guess will materially affect the results.

In reducing a census of traffic to tons per linear foot of width of

carriage-way, the deduction of the street railway tracks from the width of the street produces a marked uncertainty in the result. In places, the existence of street railway tracks may add to the traffic on the adjacent portions of the street, but this is not invariably the case, nor is there an equality in this respect in all parts of the same street. Mr. Andrews.

In studying certain traffic statistics the speaker has been in a quandary as to the value of the ton used. A difference of more than 10% will exist, depending upon the use of 2 000 or 2 240 lb. for the ton. The weight of the ton used is not stated in some instances. If traffic statistics should be expressed in kilogrammes per meter of width, this uncertainty would be done away with, and international comparisons would be easily possible. The material of the vehicles' tires should be noted in the census. It would be a matter for congratulation if some well-recognized body should inaugurate a change in the metrical system, as above suggested, and should also formulate regulations for observers of traffic, with sufficient minuteness to render possible exact comparisons between different pavements in different cities.

The speaker is of the opinion that, in the severe climates of northern cities, well-laid pavements of inorganic materials are more likely to be satisfactory than others, and he would not overlook the possibility of making an entire pavement, including the wearing surface, of cement concrete. A pavement of this description has given good satisfaction for some years in front of the Capitol at Albany, and seems well adapted to automobile traffic.

Asphalt and wood may be used where the expense will not prove a hardship to the taxpayers; they are in the nature of luxuries, like rugs and carpets on floors. Cities with mild climates, or where the lasting qualities of these perishable materials may be prolonged by other favorable conditions, may use these organic materials more freely than their less fortunate or less wealthy neighbors.

Mr. Tillson has referred to an improved asphalt pavement "made up of a 6-in. concrete base upon which is laid 2 in. of a solid binder, covered with a 1½-in. wearing surface." A pavement was constructed under the supervision of the speaker and after consultation with Colonel Greene, of the Barber Asphalt Paving Company, on Center Market, in Albany, in 1889, which was very closely in accord with the suggestion quoted. This pavement is still in good condition and has never been repaired.

The speaker is of the opinion that granite pavement may be improved by the use of stone showing some stratification, since better-shaped blocks may be obtained with such stone, and their wearing qualities are often excellent. Some method of improving the exactness of shape of stone paving blocks is certainly to be desired.

GARDNER S. WILLIAMS, M. AM. SOC. C. E.—The speaker would call attention to one phase of paving, which appears to have been wholly Mr. Williams.

Mr. Williams. overlooked, namely, the sanitary question. There is something in a pavement besides wearing qualities and costliness. An ideal pavement should be one which, with a good wearing and noiseless surface, does not give off dust, nor allow the germs which may accumulate upon it to be blown away until they can be removed by the proper agents. It is known, of course, that there is a vast difference in the surfaces of pavements in this respect and that, so far as they have gone, experiments have shown the very worst in this respect to be sheet asphalt, the best to be cedar block, and other pavements to be intermediate between these two. The speaker does not wish to be understood as saying that cedar block is the best pavement, or that it is likely to be the one adopted as ideal, but the germ-disseminating quality of a pavement is a question of prime importance, and it is a matter for surprise that none of those expert in the subject under discussion appear to have ever thought of it.

It may be said that experiments have been made by locating gelatin or agar plates at specific distances above different pavements, under various conditions of cleanliness and wind, and observing the development of bacteria on the plates; observations of the presence cr absence of dust have also been made on windy days, and such investigations have shown that the number of germs and amount of dust in the atmosphere were far greater in the case of sheet asphalt than any other, and far less in the case of cedar block.*

Maj. Beach. LANSING H. BEACH,† M. AM. SOC. C. E.—In many respects, the question of pavements is very similar to that of clothes. What is suitable for one man and one occupation is not the best for another; what is well adapted for cold weather in a northern climate is by no means that which would be selected for summer in a southern latitude, and then, too, many men wear not what they would like, but what they can afford. Similarly there is no one pavement which possesses all advantages, is best for all climates and kinds of traffic, and adapted to the purse of the poor village as well as to that of the rich metropolis. There is no such thing as the best pavement for all towns and highways any more than there is a best kind of clothes for all men under all circumstances.

The first and principal use of a pavement is to keep pedestrians out of the mud and to make traction sufficiently easy to permit the hauling of relatively large loads. The result is that the first road covering is generally of the cheapest class, often not worthy of the name of pavement. Broken stone, cobble-stones, gravel and shell have been used where such materials are obtainable at small cost. When these are not so easily procured, the community resorts to such makeshifts as the vicinity offers. Cost varies so greatly with the locality and

* See *Engineering News*, Vol. XLIV, p. 242, for a description of a series of such observations.
† Major, Corps of Engineers, U. S. A.

the materials which that locality offers, that no general comparison of expense is possible. For instance, in some parts of Ohio where paving brick are made in large quantities, vitrified brick pavements have been laid in some cases at a price as low as 35 and 40 cents per sq. yd.; this is less than the cost of macadam in many cases. Even the cost of as simple a covering as macadam varies greatly, depending upon the cost of quarrying and crushing, and length and character of haul. Cases are known where all the conditions were most favorable, and the cost did not exceed 25 cents per sq. yd.; in others, not so fortunate, the cost of similar work has been more than $1 per sq. yd. Sheet asphalt varies greatly in cost, depending upon the transportation necessary to bring the asphalt to the site. In Washington, where it can be brought in vessels, the cost is generally less than $2 per sq. yd. upon an 8-in. concrete base. In the interior of the country, the cost is higher under similar specifications. Brick pavements vary less in price perhaps than those of any other material, owing to the numerous places where such brick is made and the correspondingly large number of centers of distribution. Several of the large European capitals, London and Paris, for instance, use a wooden block pavement laid upon a thick concrete base, that in London being ordinarily 12 in. deep. The woods used are largely from Australia and New Zealand, and the cost of the finished pavement is between $4 and $5 per sq. yd., usually nearer the latter figure. There are few municipalities which can afford such an expensive covering for their streets and avenues. For a small village, or one of our new towns, with their comparatively light traffic and limited means, to attempt to use such a pavement would be as consistent as for a bricklayer or an engineer to wear broadcloth at his work. Maj. Beach.

The question of cost of a pavement includes not only that of first construction, but also the money which must be spent for maintenance. A macadam roadway traveled by many vehicles becomes costly to keep in proper condition, if the stone is at all soft, and is hardly ever an economical road covering from the maintenance point of view. Some asphalt block pavements upon residence streets in Washington have not required an expenditure of a dollar for maintenance in fifteen years.

The matter of repairs to a pavement is often, if not generally, discussed as if it were one of maintenance solely, but the fact remains that the closing of plumbers' cuts, or water-pipe or sewer trenches, or other cuts, so freely made even in new pavements, is different and requires different treatment. It is one thing to renovate the whole surface, it is another to put a patch in a good pavement so that it will not show that it is a patch and be a blemish upon an otherwise fine-appearing surface. For invisible patches, sheet asphalt is as good as any, perhaps the best, as cuts can be covered by it so as to be in-

Maj. Beach. conspicuous to a high degree. This sheet asphalt possesses, however, one great disadvantage in a town in which there is not enough of this kind of pavement to justify the establishment of a permanent asphalt plant within its limits. Cuts or trenches in such a case must wait for permanent repair until the traveling plant can make its annual or semi-annual visit to the town. This will often be found to be an important element in deciding smaller municipalities to use brick or block. A cut in a block pavement can be repaired by a good mechanic at any date desired, and need not wait for the arrival of outside parties. That many such cuts are carelessly or negligently repaired does not detract from the advantage. With proper care brick or block laid upon a cushion coat of sand or fine gravel can be relaid so that the patch will not be out of shape with the rest of the street, nor unduly conspicuous. If the city employs incompetent workmen, or does not insist upon the competent man performing his task properly, the defect should be charged where it belongs and not to the pavement itself.

The heat-retaining power of a pavement is a feature which seems to have been completely overlooked, and yet it is one which must exercise a great influence upon the comfort of the people living along the street, especially in southern latitudes. Some years ago the speaker made some experiments in Washington, which showed that macadam absorbed less heat than asphalt block, and that sheet asphalt absorbed more than any other kind of pavement. The amount of heat retained by it was sufficient to affect materially the temperature of the vicinity in hot weather. A city with a large number of asphalted streets must be hotter in summer than one with pavements of other materials.

The question is often raised as to whether or not a pavement excludes the moisture from the soil beneath it. The opinion formed from observations extending over several years in Washington was to the effect that in prolonged dry spells there was more moisture under the pavement than under the grass-covered places. The latter contain more water immediately after a heavy rain, but apparently the water, gradually diffusing itself through the ground, is retained under the pavement, while it evaporates from exposed places.

In Mr. Tillson's discussion sheet asphalt, asphalt block and bitulithic are mentioned as the varieties of asphalt pavement. There is another variety which has been coming into use in some of our smaller towns, and, while too new to permit of definite decision as to its merits, seems to promise well as an inexpensive road covering in many localities. It is formed by raking or harrowing the road surface, then sprinkling it with fluid asphalt and afterward rolling it. The method is one which may be considered as half way between the oil sprinkling of roads and the bitulithic pavement. Tar has been used in some cases instead of asphalt and appears to give good results.

After satisfactory results with one pavement, many engineers are

inclined to recommend it to the exclusion of others, but they should be careful to advise their clients according to their needs, or, at least, to show them the merits and disadvantages of the different materials and let them make their selection with a proper knowledge of the consequences. Maj. Beach.

E. M. T. Ryder, M. Am. Soc. C. E.—The speaker wishes to emphasize one point, namely, that of repairs. To a street railway man this is a serious question. The pavements of the present time are certainly not all that can be desired, and it is to be hoped that something will be discovered which will be an improvement. If joints in the track could be gotten rid of, the present trouble would be greatly diminished. The use of cast, thermit, or electrically welded joints has been considerable, but is not universal by any means. It is necessary, for instance, in the case of electrically welded joints, to have several thousand of them before it is economical to bring an electric welding plant to take care of them. It may as well be admitted that it will be necessary to take up joints in the track every once in a while, and, therefore, a pavement which would admit of doing so readily would be preferable. The pavement should be designed, not merely with reference to long life under favorable conditions, but with reference to its repair under conditions which will actually obtain. This is especially true in work where it is desired to use T-rails. There is a marked preference on the part of many city engineers for grooved rails, which undoubtedly have certain advantages, but it is an open question which type of rail is preferable, all things considered, and the decision must rest on local conditions. Mr. Ryder.

In Connecticut, most of the steam and trolley roads are controlled by the same corporation, and in certain localities it is considered very desirable to run trains, single cars, or possibly trains of two cars, from one city to another, over the main-line tracks of the steam road, and then in on the city streets in order to avoid transfers and to take people just where they want to go. This plan would afford a most convenient way for the people of the smaller towns to travel to the larger ones to transact business or to shop. In order to run trolley cars on the steam road, between the steam express trains, however, the same rate of speed is necessary for both. It would be unsafe to use the smaller flanges of the ordinary street-car wheels, or anything less than the M. C. B. standard dimensions, which practically means the use of T-rails for the street-car tracks. The only solution at the present time is to use granite dimension block along the rail, probably both inside and outside. In laying this granite block, the speaker prefers to use a tar or sand joint instead of a cement joint, because it is then more practicable to remove and replace the pavement for inspection and repairs.

A second and, of course, most important point in regard to pavements is the foundation under the track, as that often materially af-

Mr. Ryder. fects the life of the pavement. In towns where there is a good gravel foundation, no special preparation is necessary, but in some cities, where the soil is practically a brick clay, it is a very different matter. The company with which the speaker is connected has tried so-called standard styles of construction, including the use of concrete beams of great rigidity. With the concrete beams, however, the joints still have to be repaired, and these repairs have become very difficult.

The following brief description of a type of construction which has been suggested, is offered for criticism: First, make a simple rectangular concrete trough deep enough to take in the standard cross-tie and rail construction, allowing for a thin ballast of gravel under the ties and possibly a small tile drain. The supporting surface for the asphalt could be made comparatively thin, owing to the rigid, unyielding sub-foundation; possibly 3 in. of concrete laid just under the asphalt surface would be sufficient. It is a question whether any other type of construction can be found which would be preferable to the granite block for use along the rails, if a T-rail track is to be used. When it comes to renewals, the salvage with this construction would be practically complete, as the foundation is as good as new, and it is only necessary to renew the rails and ties as in an ordinary street on a gravel foundation.

The speaker would be glad to have an expression of opinion as to this type of construction, or suggestions of new types or modifications of existing types.

Mr. Lawton. WILLIAM H. LAWTON, M. AM. SOC. C. E. (by letter).—In providing for any future pavement, the constantly increasing use of auto-vehicles must be considered. Some time, no doubt, in the distant future, they will entirely supplant horses as a motive power. At present, however, both must be considered, and, for the use of either, the future pavement should be indestructible; it should be hard and rigid, but not noisy; it should be smooth, but not slippery, either wet or dry; and it should be easily kept clean.

The theoretical definition of a pavement is: An artificially improved roadbed, constructed of such durable material and presenting at all times such a smooth and firm surface as to facilitate street traffic of all kinds.

Street traffic is influenced greatly by the character and condition of the pavement, the width of the roadway, and whether encroached upon by street-car tracks.

All pavements are subjected to destructive action, principally by the combined forces of abrasion, crushing, and percussion, the latter, on account of the impact of horses' hoofs, being probably the most destructive. The weight of the loads and the grinding of the wheels are also large factors.

Its resistance to wear, or its durability, is the supreme test of

every pavement; and its form or shape is of small account. The durability of a pavement depends on its ability to withstand compression and concussion, as to brittleness; and grinding and polishing, as to toughness. It is also subjected to loss and change by wear and friction. Mr. Lawton.

Other important requisites are the imperviousness of the material and its ability to resist climatic conditions and changes. The pavement should also be sanitary, as to construction; and reasonable, as to cost and maintenance.

The relative durability of different pavements is measured by the amount of traffic each will stand before it becomes worn out. With regard to quality, there is at present no definite recognized standard except the general one derived from actual experience. Until some standard is adopted to determine the average life of different pavements, just conclusions can hardly be reached. Some standard, such as will measure the tons of traffic per square foot of area during a certain time, would seem to be most reasonable. The physical life of a pavement, as regards repairs or renewal, should also be considered. When a pavement is laid upon a prepared foundation, and is monolithic in form, or is composed of broken stone with or without mixtures, the requisite repairs may often be made economically for a long period by incorporating new material. When pavements are of block form, there comes a time when it is poor economy to repair or relay them.

The annual expense of pavements has been represented by formulas derived by assuming that their length of life bears a certain relation to their original cost. More study and experience, however, are needed to render some of the variable quantities constant.

Most pavements can be classed under two forms, either block or monolithic; and in the Northern States a solid substructure or foundation is absolutely necessary for each. The prevailing foundation is concrete, from 6 to 8 in. deep, and composed of Portland cement and crushed stone. This foundation is the integral part of the pavement itself, and, under ordinary circumstances, will endure for ages. Upon it is laid the wearing surface selected, which, as it becomes worn, may be renewed or may be replaced by one of another kind. This wearing surface, or pavement proper, should depend principally upon the nature of the street traffic and the character of the street, but local interests or political influences often prevail. Many paving companies maintain a special agent, who not only extols the merits of his wares, but prejudices in his favor the proper authorities or the adjoining property holders. All real-estate owners recognize thoroughly the value of a good pavement, as not only is the street improved in appearance, but all property in that vicinity is enhanced in value.

Mr. Lawton. There are many forms of block pavements, the principal ones being natural and artificial stone, brick, asphalt, glass, iron, cobble and wood.

The weakest part of each separate pavement is its edge, which first wears away—becomes chamfered in fact—leaving all the surface joints enlarged, and every block itself becomes rounded on top, and smooth and slippery. The concussion of horses' feet is the principal cause of this injury; and if only auto-vehicles were used, the deterioration would not occur as quickly nor extend as deep.

The blocks, also, are frequently of such size and shape, with such length of joints, that the pavement provides a poor foothold for horses.

The proper way to lay pavements is to embed them in a cushion of sand upon a heavy concrete foundation. Another important feature is the composition of the filler which is run in the joints. The best filler is made up of fine gravel and a mixture composed of asphalt and coal-tar. This mixture renders the pavement less noisy, and, as it softens and expands in warm weather, it makes expansion strips unnecessary. Liquid cement or grout is sometimes used, but it tends to make the entire pavement absolutely rigid, with no chance for expansion. Cement joints are likely to be broken by heavy traffic, and the filler, not being plastic, never runs together again.

The best stone pavements are Belgian block, of trap rock, granite, and the hard sandstones.

As to the dimensions of these blocks, the opinions of engineers vary. Where horses are the motive power, the blocks should be as wide as the horse's foot. It should be long enough not to tilt, but not so short as to present a surface which is nearly all joints. As but few stone blocks are worn out by actual street traffic, they need be only deep enough to insure perfect stability. The surface dimensions of all pavements will remain a mooted question as long as street traffic continues to be by both horse and motor power.

No artificial stone pavement has yet been invented that will compare favorably with the natural stone blocks already described.

Among the monolithic pavements, the principal ones are those composed of Portland cement and of asphalts and bitumens. The wearing surface of the former consists of a layer, about 2 in. thick, of Portland cement concrete of about equal parts, mixed on the street, and incorporated in place upon the foundation already prepared. The surface is usually blocked off, by deep grooves, into squares of the desired size. This pavement is very slippery, especially in wet or frosty weather.

All the monolithic pavements deteriorate chiefly by injury from

the impact of the calks of the horses' shoes. At present, most of the best forms of pavements mentioned, except macadam, appear to be equally serviceable for traffic by horses or auto-vehicles. Upon macadam the great dust raised by autos makes travel, not only very disagreeable, but even unsanitary. Also, the suction of the pneumatic tires, whether bound with chains or covered with leather bands full of iron rivets, destroys the binder, and ravels and scatters the crushed stone. Mr. Lawton.

Sprinkling the surface with crude oil, or coating it with some preparation of tar, improves the wearing surface very much.

Owing to these defects, plain macadam paving should be considered as unlikely to be the pavement of the future.

From some form of cement or steel will probably be derived the future pavement. Experiments have been made with solid and hollow iron blocks, also hollow iron cylinders filled with concrete, and wooden blocks capped with steel plates; but none of these has yet fulfilled the requisites of a first-class pavement.

Millions of dollars are being spent every year on city pavements, many of which are imperfect or wholly experimental. Is it not policy, then, for all municipal engineers to obtain, in a thorough and systematic manner, all the reliable data in relation to the wear of traffic in classified pavements?

Can the relative comparison of one pavement with another be made in any other way?

Is not this the only scientific method by which proper data may be obtained for guidance in the construction of the perfect future pavement?

Philip W. Henry, Assoc. M. Am. Soc. C. E.* (by letter).—Pavements of the present may be divided, as to origin, into two classes, mineral and vegetable, and, as to surface, into two classes, sheet and block. As cheapness and durability are characteristics of mineral as against vegetable, and as noiselessness and ease of traction are characteristics of sheet as against block, it is evident that the pavement of the future will be of mineral origin, laid in an unbroken surface. Mr. Henry.

Existing pavements of mineral origin laid in sheet form are macadam and asphalt, both of which consist of mineral particles bound together with some sort of cementing material, differing only in kind, and in quality and size of particles. No doubt the pavement of the future will consist of mineral particles of the proper quality, proper size and proper cementing material. Just what will prove to be "proper" is a matter which will now be discussed. It is understood that in this discussion only the wearing surface will be considered, as it is assumed that in any case a suitable foundation will be adopted, whether such foundation consists of Portland cement concrete or other rigid material.

Mr. Henry. *Quality of Mineral Particles.*—In both macadam and asphalt pavements, while limestone and other soft stones have been used successfully in foundations, experience has proven that a hard tough stone must be used for the wearing surface. Thus trap rock, granite, or flinty limestone are preferable to the ordinary limestone, which, under traffic, is soon reduced to powder, necessitating constant repairs. For asphalt pavements, a siliceous sand is used almost exclusively, owing both to its abundance and to its wearing qualities. In some sections a shale or a calcareous sand has been used with satisfactory results where the particles are so small as to resist crushing. As a general proposition, however, it may be assumed that the pavement of the future will be composed of mineral particles of some hard, durable stone, such as quartz, trap rock or granite.

Size of Mineral Particles.—While the quality of the mineral particles may be considered as definitely settled by past experience in favor of a hard, durable stone, there is still a difference of opinion as to the proper size of these particles. It is generally conceded, however, that whether the largest particle is from 1 in. to 2 in. in diameter, as in macadam; or whether it is $\frac{1}{10}$ in. in diameter, as in asphalt pavements, the different particles, from large to small, must be graded in size so as to produce a minimum of voids. Thus, no matter what the size of the largest particle, there must be a sufficient number of fine particles to bring about that compactness and density so essential for durability. It is doubtful if this grading of particles has received much attention from those who lay ordinary macadam. This matter, however, has received most careful study and attention from those who lay that form of bituminous macadam called "bitulithic," which was introduced into America about five years ago, and since then has been laid in many cities throughout the United States and Canada. No doubt the success which this pavement has had over other bituminous macadams is largely due to the great care observed in proportioning the different sizes of mineral particles entering into its composition, beginning with 1 in. or $1\frac{1}{2}$ in. as the largest size, and continuing in definite proportions down to $\frac{1}{200}$ in. and less in diameter. By both theory and experience it has been found that certain definite proportions of different-sized grains are essential to produce the best results.

When the asphalt pavement, as known in America, was introduced, some thirty years ago, the necessity of proper sand grading was well appreciated, but in the effort to extend the business, demanding so much time and energy, the technical side was for a time neglected.

In the early days of the industry, pavements laid in different

cities, with apparently the same proportions of sand and asphalt cement, gave very different results; and upon investigation it was shown that this difference was largely due to variation in the sand grading. At the present time it is well understood that, for the best results under heavy traffic, there should be a certain proportion of mineral particles $\frac{1}{10}$ in. in diameter, a certain proportion $\frac{1}{20}$ in. in diameter, and so on, down to impalpable powder. As this definite sand grading is not generally found in any one deposit, it is customary to mix sands from different deposits. As very few sands carry much 200-mesh material, it is customary to supply this very fine material in the shape of ground limestone or Portland cement. Mr. Henry.

In macadam the largest particle is from 1 in. to 2 in. in diameter, and in asphalt pavements the largest particle is $\frac{1}{10}$ in. in diameter. In the pavement of the future it is likely that both these gradings will be used, the coarser grading on streets of light traffic where there is little danger of crushing, and the finer grading on streets of heavy traffic where compactness and uniformity are essential.

Kind of Cementing Material.—In ordinary macadam dependence is placed upon the stone or gravel itself for cementing material. Some limestones and gravels contain a certain amount of cementing material, and when properly watered and rolled the mineral particles will be tightly held together. Under heavy traffic, however, and especially since the introduction of the automobile, the finer particles in the macadam are soon separated and converted into dust. To overcome this difficulty, there have been introduced, for sprinkling macadam, various compounds, such as mixtures of water and calcium chloride, water and saponified oil, special crude oils, special products of coal tar, etc. All these, however, are useful only under the lightest form of traffic, and have as their chief recommendations the cheapness and ease with which they can be applied. This sprinkling is effectual only on the upper layer of particles, as the various solutions have comparatively little penetrating effect.

In order to get the best results it is necessary to coat each mineral particle with some kind of a cementing material, and to lay this mixture to a depth of from 1½ to 3 in., depending upon the amount of traffic. As cementing materials, both Portland cement and bituminous cement have been used. While Portland cement has been tried in various cities for a number of years, the results under heavy traffic have not been satisfactory, owing chiefly to the rigidity of the wearing surface, which would not stand the blows of traffic. Under light traffic, however, with proper attention to the grading of mineral particles, as above mentioned, there is, perhaps,

Mr. Henry. a future for Portland cement owing to its cheapness as compared with bituminous cement.

For many years, both in America and in Europe, bituminous cement in the form of coal tar has been used in the paving industry. Such pavements have been known as "tar macadam," "coal-tar pavements," "concrete pavements," etc. Owing, however, to its lack of uniformity and its volatility under the rays of the sun, coal-tar was practically abandoned upon the introduction of asphalt pavements. Within the past five years coal-tar has again been used extensively in bituminous macadam or bitulithic pavements. Whether a better and more uniform grade of coal-tar is now being produced than was the case thirty years ago is a question which time alone can determine. Owing to its cheapness, as compared with asphalt, coal-tar will doubtless be used in the future, as it is to-day, on streets of light traffic, but, owing to its susceptibility to changes of temperature and its more volatile nature, it is doubtful if it will be used for pavements subjected to heavy traffic.

The word, "asphalt," first applied to pavements was the "asphalte comprimé," known in America as "rock asphalt," laid in Paris in 1854. This was a limestone impregnated with bitumen, found in Switzerland, and later in France, Germany, Sicily, and other parts of Europe. To this day practically all the asphalt pavements of Europe are rock asphalt. On the other hand, in America there are very few rock asphalt pavements, due largely to the high cost of European rock asphalts, and to the inferior quality of those of America.

Practically all the asphalt pavements of America are composed of mineral particles cemented together with "asphalt cement." This mixture was devised by Edward J. De Smedt, a Belgian chemist, who came to America in 1861, and took out his first patents in 1870. The "asphalt cement" was composed of Trinidad asphalt, fluxed to the proper consistency with petroleum residuum; and the mineral particles were composed of sand and powdered carbonate of lime. This is still the combination used in many of the asphalt pavements of the present day. For twenty years or more Trinidad asphalt was used exclusively as the cementing material, but in 1893 an asphalt, occurring in Venezuela about 100 miles from the Trinidad deposit, known as Bermudez asphalt, was introduced, and has been used extensively ever since in the paving trade.

During the past six or eight years, in addition to natural asphalts, such as Trinidad, Bermudez, Cuban, Maracaibo, etc., there have been introduced bitumens manufactured from petroleums having an asphaltic base. These bitumens are known as "oil asphalts," "artificial asphalts," or "residual pitches." Just what part these particular products of petroleum will play in the asphalt pavements of the future, is a question which only time can determine.

Mr. Henry.

There is no doubt that the natural asphalts are also products of petroleum, resulting from Nature's process of distillation. The crude petroleum has been forced to the surface by pressure from below, flowing down watercourses, as in Mexico; spreading over swamps, as in Venezuela; or filling the crater of an extinct mud volcano, as in Trinidad. Nature's distilling process, extending as it does for years, at the temperature of the sun, combined with the effect of the winds and rains, produces an asphalt well adapted for use in pavements which are exposed to all sorts of climatic conditions.

As there have been advances in the proper grading of mineral particles, so there have been advances in the proper consistency and proportions of asphalt cement. Various fluxes have been used for softening the natural asphalts, all of which are too hard in themselves. With some asphalts, results are apparently the same, whether the flux is made from the paraffine petroleums of the East, the semi-asphaltic petroleums of Texas and Kansas, or the asphaltic petroleums of California. With other asphalts the California fluxes give the best results; but, whatever the flux, it is generally considered that a certain consistency (known as penetration) of asphalt cement is desirable for certain conditions of traffic and climate, and well-recognized standards have been established.

There is still some difference of opinion as to the exact proportion of asphalt cement to be used in the paving mixture. This depends so much upon the kind of sand and dust, that no definite rule can be laid down. No doubt the future will bring about the solution of this problem along with many others.

Conclusion.—No doubt the development of the future will be in the line of various grades of macadam and asphalt, depending chiefly upon the kind and amount of traffic. That macadam is already the standard, for country roads and suburban districts all over the world, is well known, and no doubt an improved form of macadam will remain the standard of the future for this class of roadways. Like macadam, asphalt has become a standard form of pavement, especially for cities.

In 1876 Congress appointed a Commission, composed of the architect of the Capitol and two officers of the Engineer Corps, to select the best kind of pavement for Pennsylvania Avenue, Washington, to replace the wooden blocks laid only a few years previously. In all, there were more than forty proposals, representing all sorts of paving materials. Out of all these proposals, the Commission selected rock asphalt for one-third of the Avenue, and the "artificial siliceous" asphalt pavement (the ordinary asphalt pavement of to-day) for the other two-thirds. As up to that time there had been laid only 20 000 sq. yd. of the "artificial siliceous" as-

Mr. Henry. phalt pavement, the oldest less than five years, the Commission may be said to have had the courage of its convictions. That its judgment was correct is evident from the fact that in 1907 when the repaving of Pennsylvania Avenue again came up for decision, no other material for the entire Avenue was considered than that same variety of asphalt pavement, which, thirty-one years before, was selected for paving two-thirds of the Avenue.

Since that original selection, more than 60 000 000 sq. yd. of asphalt pavement have been laid in the United States and Canada, of which 18 000 000 sq. yd. have been laid in the past three years.

That other forms of pavement, such as stone blocks, brick, wood, etc., will remain in use, under conditions best adapted to these particular materials, is conceded, but the great development of the future will be along the line of macadam and asphalt, both of which have passed the experimental stage, and in both of which there are still greater possibilities.

Mr. Bienenfeld B. Bienenfeld, M. Am. Soc. C. E. (by letter).—The rapid development and increasing use of the horseless carriage, or automobile, point to a largely extended and constantly increasing demand for smooth pavements. For many years, however, horses and other draft animals will be in evidence upon our streets, and provision must be made in the future, as at present, to facilitate the tractive efforts of these beasts of burden. On grades, and where heavy loads are to be hauled by animals, stone and brick, and possibly wood, will continue in use; but, as paving materials, these three substances possess many patent disadvantages, and their use will always be restricted to cases where the smoother and more ideal pavement is undesirable or unattainable.

The tendency toward the building of smooth, impervious, noiseless, dustless, monolithic, sheet-pavements is therefore ever on the increase. With the lights now before us, there is no reason to apprehend a falling off in that tendency. This will necessitate a large and reasonably cheap supply of asphalt. The asphalt fields of Europe, the West Indies, and South America, will continue to yield a reasonably large and cheap supply. Since their first exploitation in 1893, the asphalt-oil fields of California have given to the world an additional supply of asphalt; and it is possible that the asphalt-oil fields of Mexico may, in the future, be counted on as an additional source of supply.

As first made in California, the so-called oil-asphalt, produced by inexperienced manufacturers and laid by unskilled pavers, gave results which were far from acceptable; but, after fourteen years of experience in manufacture and laying, it may now be said that paving asphalt is being, and can be, produced from California oil, which is equal, if not superior, to any asphalt produced from any

other source. It is, of course, the custom and habit of persons representing special interests still to condemn and to "damn with faint praise," this so-called "artificial" asphalt. But as "the proof of the pudding is the eating," so the proof of this asphalt is its wearing, and the constantly and rapidly increasing demand for it. It has found its way into successful paying use in nearly all the large cities of the United States and Canada. Mr. Bienenfeld

During 1905, the latest year for which any statistical data are available, there were produced in California 50 000 short tons of oil-asphalt, which is the equivalent of 87 000 tons of refined Trinidad asphalt. In the fiscal year ending June 30th, 1905, the total asphalt imports into the United States from all foreign sources were 157 000 tons of crude, dried, "advanced," and rock asphalts. These crude materials contain from 20 to 70% of bitumen, whereas the California material contains more than 99% of bitumen. Allowing an average of 50% of bitumen in the imported asphalts, which is an excessive estimate, their total bitumen paving value would be 78 500 tons, as against the 50 000 tons of the California production. It is evident, therefore, that California, according to the latest data, is supplying about 40% of the asphalt requirements of the United States.

The oil production of California, which is to-day larger than that of any other State in the Union, is still increasing, through the discovery of new fields and the extension of the older ones; and there is every reason to believe that its asphalt production will be amply able to meet all demands that may arise in the next decade or two. In 1905, California produced 34 000 000 bbl. of oil, having an asphalt content of about 1 250 000 tons of pure, paving bitumen, of which only 50 000 tons, or 4%, were actually manufactured to meet current demands, the remaining possible 96% having been consumed as fuel.

The Republic of Mexico is at present producing asphaltic-oil, and may in the future enter the ranks as an important asphalt-producer, thus adding to the sources of asphalt supply. It is to be hoped that the producers of Mexican asphalt will profit by the early experiences and mistakes of the California manufacturers; and that they will allow no material to leave their refineries which is not in all respects acceptable and suitable for paving purposes. Care and technical skill are requisite; without these, the results are likely to be very unsatisfactory and possibly disastrous. For some time to come, however, all the Mexican oil production will probably be required to meet the fuel demands of that republic; and some years may elapse before Mexico can become an important asphalt producer. Its oil resources are at present largely undeveloped; and its asphalt possibilities are therefore as yet unknown.

Mr. Bienenfeld The oil resources of other and more distant portions of the globe are still in reserve, unexploited. It is likely that some of them contain true asphaltic oil, similar to, if not identical with, the asphalt-oils of California. The asphalt resources of the West Indies and of South America are by no means exhausted. There is in sight, therefore, for future use, an ample supply of acceptable asphalt; and all the indications and tendencies of to-day make for a larger use of this paving material of the present in the construction of the pavements of the future.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

ELECTRIC RAILWAYS.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"(*a*) What are the factors which determine the maximum economical grade for electric railways?

"(*b*) In establishing direct lines with heavy grades, under what conditions will it be found practicable to use electric locomotives and gas-engine generating stations, rather than traction by steam locomotives?"

BY MESSRS. W. W. FOLLETT AND J. T. NOBLE ANDERSON.

W. W. FOLLETT, M. AM. SOC. C. E.—Referring to the electrification of Soldier's Summit hill on the Rio Grande Western Railroad, in Utah, to which reference has been made, some twelve years ago, the speaker had a long conversation with General William J. Palmer, then President and principal owner of the Rio Grande Western, concerning the use of electrical power on this hill. After a thorough consideration of the subject, the conclusion was reached that the traffic was not heavy enough to stand the expense of electrification, that is, that the train movements were not frequent enough. General Palmer dropped the matter and never took it up again. Mr. Follett.

When trains are handled by electrical power, there must be a large volume of traffic, else the interest on the capitalization of the outfit, cost of keeping the lines charged all the time, including the loss of power by induction, and the expense of electrical repairs, will be so

* Continued from August, 1907, *Proceedings*.

Mr. Follett. great as to outweigh the advantages. Of course, where train movements are frequent, there is probably no question as to the economy and advantages which follow the use of electricity.

Mr. Anderson J. T. NOBLE ANDERSON, M. AM. SOC. C. E.—The speaker would mention an electric railway that is being constructed in New Zealand. The west coast of New Zealand is separated from the east coast by a long range of snow-clad mountains, in a manner somewhat similar, except on a smaller scale, to the way in which the Rockies separate the east and west coasts of the United States.

Some 12 or 14 years ago a British company, the Midland Railway Company, was organized and obtained large concessions of land for the construction of a railway to connect the coasts of New Zealand. After struggling with the problem for about eight years, the company finally abandoned the work, and the Government of New Zealand is now constructing the connection. The work as now designed, however, is quite different from what it was originally. The chief reason for alteration was that, owing to the fact that much steeper grades can now be used, the ruling grade being 1 in 25, a single-track tunnel about 6 miles long with heavy drainage grades has not been feared. The tunnel runs under a mountain ridge between 4 000 and 5 000 ft. above the level of the line that passes under it; and the rise in the tunnel is steeper, it is thought, than any of the Alpine tunnels between Switzerland and Italy. Of course, with electric plant, etc., there is no difficulty, and in that mountainous country, with the Bulwer River flowing past, there is no lack of water power. All the railways of New Zealand will eventually be run by electricity.

One other point: in his practice in New Zealand the speaker has found it expedient to use Diesel oil engines. These engines are used in the various cities in Great Britain and Europe for tramway traffic. All the tramways in Moscow are also run by these engines, but as yet they do not seem to be much known in the United States. They are known to the scientific men, however, and have been written about by Lord Kelvin. Mechanical engineers appreciate what the Diesel engine is, since it can be run with crude oil; it is an engine that requires only one attendant, and, as compared with an ordinary gas engine, has the advantage that it can be run at any desired speed. It can also be run at about a quarter or half its rated capacity and practically as good economy results as when it is run under full load. For tramway work, running with very variable load, is a very important factor, and an engine which can be run under one-third its capacity as economically as under a full load is of importance to everybody. Diesel engines are used for the whole 24 hours of the day at a cost which, including interest on the plant, amounts, in England, to about £8 ($40) per h.p. per annum; many of them, if located where crude oil is cheap, give even better results.

The speaker would like to say more about these engines, because the results obtained with them have justified the opinion he had formed from reports from such men as Lord Kelvin, and because they have exceeded all his expectations. In two particular cases where he used them, the speaker, owing to New Zealand being so far from the manufacturing point, took the precaution to have very clear specifications, making the manufacturers subject to heavy damages if the engines did not come up to the guaranty, and in both cases they are doing better than was called for by the guaranty. Mr. Anderson.

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COMPARISON OF RAINFALL AND RUN-OFF IN THE NORTHEASTERN UNITED STATES.

Discussion.*

By Messrs. E. C. Murphy, Charles A. Holden, H. C. Frankenfield and Alfred J. Henry, and Thaddeus Merriman.

Mr. Murphy.

E. C. Murphy, Assoc. M. Am. Soc. C. E. (by letter).—The writer believes that the data available for computing run-off from precipitation will not justify the use of this method for estimating stream flow, even in the eastern part of the United States, where the number of precipitation stations per unit area is largest and the records longest. His opinion is based on measurements of run-off and a study of the corresponding precipitation data. He has observed large floods on streams, that the precipitation data do not indicate, because the stations were too few; he has also observed annual run-off larger than the observed annual precipitation, due to the stations not being properly located with respect to altitude. He believes that writers on this subject do not, as a rule, treat it fairly. While they admit that the available data are unsatisfactory at best—on account of lack of funds for its collection, and lack of data for computing the effect of some of the quantities upon which run-off depends—nevertheless, they draw conclusions from their results as if the data were good and complete, and intimate that the results obtained by this method are as good, if not better, than those obtained by gauging. They subject their data, such

* This discussion (of the paper by John C. Hoyt, Assoc. M. Am. Soc. C. E., printed in *Proceedings* for May, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

as they are, to various mathematical processes which have little, if any, experimental basis, and in some mysterious way much value is imparted to them. To illustrate: a recent user of this method, when he found the measured monthly precipitation at any station more than twice the mean for that month, substituted the mean for the observed quantity. That is, when perchance one of the few precipitation stations was near the center of a storm area, and its record was approximately the rainfall corresponding to the measured run-off, he threw away the record and used in its place a quantity less than half the observed quantity. By this and similar processes he finally obtained what he called "deduced mean annual dependable precipitation." His computed run-off is so reliable that "stream gaugings were only used as a guide." Mr. Murphy.

Run-off is a resultant quantity; its value depends upon several quantities or factors. It can be obtained directly by measurement of the flow of the streams, or it can be computed from the measurements and proper combination of the quantities upon which it depends. Precipitation, while the most important, is only one of these factors; temperature, wind velocity, barometric pressure, surface and ground storage, shape and extent, inclination and character of water-shed, extent of forest and cultivated area, are other factors. This is the formidable array of quantities which the user of this method must properly reckon with in order to get a reasonably accurate estimate of run-off.

Let us see with what accuracy precipitation on a drainage basin is measured. It is admitted by all that precipitation is an erratic phenomenon; it does not follow any known law; it cannot be obtained by any mathematical process, and the only way to obtain its accurate value is by measurement or observation. The monthly precipitation at two stations only a few miles apart may differ more than 25 per cent. It varies in irregular cycles, but this knowledge does not help in the least in supplying missing data. It is seen to depend on elevation, topography and direction of the prevailing wind, but there are not sufficient data to enable the effect of these conditions to be computed with reasonable accuracy.

A measurement of rainfall is subject to two errors from air-currents, which may amount to 25% of the catch. Snow measurements are subject to larger error than rainfall measurements. A rain-gauge has a diameter of only 8 in. and shows the rain falling on an area of less than 0.35 sq. ft. What confidence can be placed in the precipitation on a water-shed computed from available data? Take, for example, the Susquehanna River water-shed, above Williamsport, Pa., mentioned by the author. There are eight precipitation stations in an area of 5 640 sq. miles—one station to 725 sq. miles. The precipitation on 725 sq. miles is computed from that on less than half a square

Mr. Murphy. foot. This station is located of necessity at a convenient place, each measurement is subject to an error of 25% of the catch, and the law of change between stations is not known. The engineer has very little confidence in such data, and will only use it for rough preliminary estimates.

Wind movement is neglected entirely. From evaporation measurements it is known that the loss from a body of water increases as rapidly as the wind velocity increases. How is it possible to get such reliable estimates of run-off by this method, when so important a quantity as wind movement is neglected?

In striking contrast with all this uncertainty from lack of data is the simple direct method of obtaining run-off by gauging the streams. This method gives the run-off for each month and day, as well as the annual run-off. If a meteorological station were maintained in each township (36 sq. miles) where not only precipitation, temperature, wind velocity, and atmospheric pressure, but all the other quantities upon which run-off depends, were measured, data would then be available for a reasonably accurate estimate of run-off from rainfall. It would be folly, however, to spend so large a sum for run-off data, when the run-off can be measured for a much less sum.

In the early days of the settlement of this country, there was a great demand for meteorological data, mainly for agricultural purposes, and no demand for run-off data; at the present time there is a great demand in many parts of the country for run-off data. Stream gauging alone can satisfy this demand.

The writer does not wish to convey the idea that the method of computing run-off from precipitation should never be used. It may be used with profit in some sections of the country in connection with stream gauging. If, for example, the flow of a stream at a given place is known from stream gaugings for, say, three years, and the precipitation over the basin is also known, with a reasonable accuracy, for these same three years and, say, the preceding five years, then an approximate estimate of the annual run-off for the latter period may be computed from the precipitation of that period, together with a comparison of precipitation and run-off for the former period when the gaugings were made. In other words, this method may be used to supplement stream-gauging records, but to compute run-off from meteorological data without gaugings appears, to the writer, to be a waste of time.

Mr. Holden. CHARLES A. HOLDEN, ASSOC. AM. SOC. C. E. (by letter).—The writer is in hearty accord with the efforts of Mr. Hoyt to bring about the estimation of available water supply through the use of run-off data instead of the comparatively uncertain precipitation data.

Precipitation data must always give a very imperfect record since, of necessity, observation stations are situated only at infrequent in-

Mr. Holden.

tervals and at varying positions in elevation. All are familiar with the phenomenon of heavy rain in one section and little or none within 2 or 3 miles or even less. There are also many other factors to be considered, account for which can be made but imperfectly. The quantity of water running off, as the author points out, will depend upon the stage of the ground water. It, as well as the ground water, will depend upon whether the ground is or is not frozen, the character of the soil, the amount of wooded and tillage area, and the topographic and geologic configuration of the tract under discussion.

The case in point is well illustrated by Table 2* and is even better shown by diagrams which the writer prepared in connection with his work as Resident Hydrographer at the Orford Station in 1900-04. On these diagrams the points, in different years, for maximum and minimum rainfall are not in the same relation to the points for maximum and minimum run-off in the table above referred to.

The order in amount of precipitation for January is 1902-03, 1904-05, 1903-04, 1901-02, 1900-01.

The order for amount of run-off in January is 1901-02, 1902-03, 1900-01, 1904-05, 1903-04.

The order for amount of run-off in February is 1902-03, 1900-01, 1901-02, 1903-04, 1904-05.

The order in amount of precipitation for July is 1904-05, 1900-01, 1902-03, 1901-02, 1903-04.

The order for amount of run-off in July is 1901-02, 1904-05, 1900-01, 1902-03, 1903-04.

The order for amount of run-off in August is 1901-02, 1900-01, 1904-05, 1902-03, 1903-04.

For the entire periods chosen the order in amount of precipitation is 1901-02, 1900-01, 1903-04, 1902-03, 1904-05, while the order for run-off is 1901-02, 1900-01, 1902-03, 1904-05, 1903-04.

The run-off in percentage of precipitation for the periods shown varies more than 20% from the mean, and the largest is nearly one and one-half times the smallest.

The valuable work in stream gauging, undertaken by the United States Geological Survey, ought not to be curtailed in efficiency by reason of lack of funds for the prosecution of the work.

It is also of great importance that further investigations should be made to determine better constants for guidance in gauging rivers through the ice, and that greater effort should be made either to take the gauge heights to the water, or else to obtain more frequently the thickness of the ice under the gauging point.

Messrs. Frankenfield and Henry.

MESSRS. H. C. FRANKENFIELD† and ALFRED J. HENRY† (by letter). —At the regular stations of the United States Weather Bureau in

* *Proceedings*, Am. Soc. C. E., May, 1907, p. 468.

† Asst. Chfs., Forecast Div., U. S. Weather Bureau.

Messrs. Frankenfield and Henry. large cities rain gauges are generally exposed on roofs of office buildings. These exposures, while not satisfactory in all respects, are the best that can be had under the circumstances.

In winter, when roof exposures are most objectionable, the snowfall is measured in the open at some distance from buildings or other obstructions, and at a point where drifting is least pronounced.

The rain gauges at co-operative stations of the Bureau are generally located on the ground, 40 or 50 ft. distant from surrounding objects, and the exposures are considered good. The total precipitation from both classes of stations, regular and co-operative, are platted each month on large scale maps of the United States. By this means it is possible to discover improbable values and incorrect reports. This method also affords a means of comparison between roof and ground exposures, since there is generally one or more ground-exposed gauges near Weather Bureau stations in large cities. The monthly charts of precipitation, on which the rainfall values from both classes of exposure are spread indiscriminately, show no differences of importance. The natural variation in the rainfall between any two places within a short distance of each other is much greater than any discrepancy that may appear between the catch of a roof-gauge and that of a ground-gauge.

The need of rainfall stations at high altitudes is fully realized by the Weather Bureau. A few years ago an attempt was made to increase the number of high-altitude stations through co-operation with the Forestry Service of the Department of Agriculture, but the plan failed. The Bureau now maintains, on the head-waters of some rivers, a number of rainfall stations at an average expense of $100 per annum for each station. The greater majority of its rainfall stations, however, are operated by private persons who do the work without compensation; the field of observation for this class of persons is naturally limited to the habited areas, and to those which almost without exception are found in the valleys and low levels. In the Far West and at great altitudes, the question is further complicated by the extreme difficulty of measuring precipitation when it is mostly in the form of snow and badly drifted by the winds. During the winter of 1906-07, a special form of snow-gauge was devised and placed on the summit of the Sierra Nevada and at other stations. It is expected that the experience gained by the use of this instrument will be useful in solving the instrumental problem. The great desideratum, however, is, and always will be, persons to do the work at remote places and in high altitudes. An increase in the number of high-level stations is included in a project for the reorganization of Weather Bureau work now under consideration.

In determining the mean precipitation for the several drainage basins, the author takes the average of the whole number of rainfall

Messrs. Frankenfield and Henry.

stations in each basin. For relatively small areas this plan works well, and the results are probably as near the truth as can be obtained with the number of rainfall stations available. The greater the number of well placed stations, the greater will be the accuracy of the district means.

The precipitation during the cold months is more evenly distributed than that of the warm months, and, therefore, the means will be more dependable than those of the warm months. Owing to the very unequal distribution of precipitation in summer within quite limited areas, a large quantity of water may be precipitated over the headwaters of a stream, and yet none will be caught in any rain-gauge in the district. It is not advisable to draw hard and fast conclusions from either short periods of time or for small areas, but an attempt should be made to follow each and every individual case of heavy rain and to note its effect on the flow of the stream for all the varying conditions of soil and slope in the drainage area. As the author has pointed out, the run-off of one month may be almost wholly controlled by the rainfall of a previous month. It would be interesting to know how much time may elapse between the initial and the concluding effect of a heavy fall of rain on the drainage below; in other words, to note how long, whether one, two, or three months, a single heavy rain or several days of continued heavy rains will perceptibly affect the run-off of the stream below, and thus determine the general characteristics of each drainage area.

It is obvious that the manner in which the rain falls, whether as a steady rain of moderate intensity or as a heavy dash of great intensity, is of much importance in determining the relation between rainfall and run-off. In collecting the information contained in his paper, the author has performed a valuable service. It is hoped that the work may be carried on until at least 30 years' data have been accumulated, since there is a possibility that faulty conclusions may be drawn when the subject is considered in the light of a few years' observations only.

Mr. Merriman.

THADDEUS MERRIMAN, JUN. AM. SOC. C. E.—The author in this paper has brought together and digested in an admirable manner some of the results of the work done during the past ten years or more by the United States Geological Survey. Such an extensive compilation and comparative study of these results has, the speaker believes, been nowhere else attempted.

The author confines his discussion to nine of the larger streams in the northeastern section of this country and analyzes the stream flow past fourteen stations situated at different points on these streams. From the results of these studies, he draws the general conclusion that the annual run-off from any stream in this section of the country can be predicted from the run-off data which are now available. The speaker

Mr. Merriman. believes that this conclusion is so broad that, even if the data on which it is based were most perfect, it could not be justified. Every stream is a law unto itself, both on account of the fact that the amount of rain which falls upon it differs from that which falls upon its immediate neighbor, and also on account of its physical characteristics, most important among which are its altitude above sea-level, its mean annual temperature, and last, but not least, its slope or steepness. All these factors combined may influence the run-off to such an extent that it is not unusual to find two streams which are within a comparatively short distance of each other and which, to all outward appearances, have the same physical characteristics; yet the yearly run-off of these streams will differ by more than 25 per cent. This is true as between the Tohickon and the Neshaminy Creeks in Pennsylvania, the Esopus, the Catskill and the East and West Canada Creeks in New York. The author's contention may be true when applied to streams having drainage areas of 5 000 or 6 000 sq. miles. On a stream of this size, the causes of difference enumerated by the speaker will average up to such an extent that run-off data may be safely used for purposes of estimating. Such large streams, however, are few; most studies and estimates are made on smaller streams, each of which has its own characteristics and must, therefore, be studied by itself. The speaker submits that the laws which govern the flow of a large stream are not applicable to the flow of a smaller stream, even if the latter be a tributary of the former.

The results obtained by the author indicate that the run-off from the streams studied is somewhat greater than has heretofore been supposed. For instance, the run-off from the Housatonic River above Gaylordsville, Conn., is shown to be 62%, while it is known that the Croton River, on the same average rainfall, will yield but 48%, this too in spite of the fact that the water-shed of the Housatonic is nearly three times as great as that of the Croton. Again, the percentage of run-off, as shown for the James and the Roanoke Rivers, approaches very nearly to that of the Sudbury, notwithstanding that the rainfall on the Sudbury is greater than on either of the other streams, and that it is situated in a considerably colder climate. Again, if the run-off from the Pequannock is compared with that from the Housatonic, as given by the author, it is found to be roughly 5% less, and this, too, from a water-shed which is far steeper, and on which the rainfall is materially greater.

The gaugings on all the streams discussed by the author were made by the United States Geological Survey by current-meter methods, whereas those on the Sudbury, Croton and Pequannock are the results of other methods of measurement. The precision of the results deduced from any series of observations depends on the accuracy of those observations, and it is to be regretted, therefore, that the author

has not indicated his opinion of the value of the data used in his discussion. Mr. Merriman.

The speaker is well aware that the methods used in the measurement of stream flow are approximate only. The unknown factors and changeable conditions which enter into them are so many that they have not as yet been co-ordinated. Practically all the stream-gauging work of the United States Geological Survey has been done by the current-meter method. The instrument used is the small Price meter, which is occasionally rated in still water. Gaugings are made from time to time at the stations where the discharge is to be measured, and, from these gaugings, a discharge curve for varying gauge heights is constructed. The gauge is then read, to the nearest half-tenth of a foot, twice daily by an observer who lives in the vicinity of the station. Most stations are located on bridges, and, at many of them, particularly across the larger streams, there are one or more piers in the river.

The accuracy of the determination of the yearly discharge of a stream measured in such a manner is dependent both on the accuracy of the measurements from which the discharge curve is determined and also on the daily observations of the gauge height; of these two main conditions that which is perhaps most likely to be in error is the former. In the readings of the daily gauge heights it is probable there will be as many plus as minus errors, and that, consequently, errors due to this cause will balance each other.

The accuracy of the method is, therefore, almost entirely, if all other conditions are the same, dependent on the accuracy of the determinations of the discharge curve, if no account be taken of the unfortunate location of gauging stations on bridges which have piers in the river and where the hydraulic conditions, consequently, are much disturbed.

The current meter of the Price type with which the discharge measurements are made is usually suspended by a cable, and the velocities for each section determined by the point method holding the meter at the six-tenths depth. This meter is, the speaker believes, not well adapted to the measurement of water velocities which exceed 2 ft. per sec., in that the results given are too high, and also for the following reasons:

(*a*).—The meter is usually rated in still water where all particles of the water impinge on it in parallel lines. In flowing water, therefore, where the particles move in many different directions, the meter will, since it is constructed to be more sensitive in one direction than in the other, record a velocity which is higher than the mean velocity at the point where the meter is held.

(*b*).—The meter will respond to a current which impinges on it in any horizontal direction and, consequently, will record the velocity at the point where it is held, no matter whether the direction of the

Mr. Merriman. current is at right angles to the cross-section where the discharge is being measured or not.

(*c*).—The meter has inertia and, therefore, will not immediately respond to a slackening of the current. This is also true as the result of its mechanical form, and, consequently, the velocity it records is greater than the mean velocity at the point where it is held on account of the pulsation of the moving water.

(*d*).—The meter, when suspended by a cable, swings back and forth like a pendulum, thus increasing the effect of the pulsations in the current.

In view of the differences between the results of the gaugings set forth in this paper, when compared with other and reliable long-term gaugings on other streams, and after having made careful allowances for the differences due to variable conditions on the water-sheds themselves, the speaker is of the opinion that there is sufficient evidence to indicate that the results for the run-off shown in this paper are uniformly too large, and that the discrepancy is approximately 10 per cent.

He believes that this excess in the yearly totals is largely due to the difficulty of measuring flood discharges with a current meter, and, since in an ordinary year considerably more than 60% of the total flow occurs at high or flood stages of the river, it becomes evident that a method to determine successfully the total yearly flow of a stream must first accurately measure the volume of water carried by a river during its high stages.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

CHARLES BLACKWELL, M. Am. Soc. C. E.*

DIED DECEMBER 29TH, 1906.

Charles Blackwell was born at Devizes, Wiltshire, England, on February 4th, 1843. He was the eldest son of Thomas Evans Blackwell, the first Vice-President and General Manager of the Grand Trunk Railway System, and came to Canada with his father in 1857. He was descended from a family of engineers, his grandfather, Thomas Blackwell, having built several stone bridges over the river Avon near his native town of Devizes, Wiltshire. His father, Thomas Evans Blackwell, was the first Hydraulic Engineer in England, and built the Kennet and Avon Canal. Mr. Blackwell attended the High School and McGill College at Montreal.

In 1860 he entered the service of the Grand Trunk Railway Company, where he remained until 1869, being employed principally in the Motive Power Department. From 1869 to 1876 he was engaged upon the location and construction of the Intercolonial Railway, having charge of a 22-mile section for three years, and of a 74-mile section for two years of this time. During this latter period he had supervision of the equipment and of the erection of the machinery in the principal repair shops at Moncton, New Brunswick.

During 1876 and 1877 he was Resident Engineer in charge of the completion of 45 miles of the Quebec, Montreal, Ottawa and Occidental Railway. From 1877 to 1879 he had charge, as Resident Engineer, of the improvement and construction of the Quebec Central Railway. In 1879 he was appointed Mechanical Engineer of the Dominion Department of Railways and Canals, and had prepared, under his direction, detailed specifications and drawings for the construction of all kinds of rolling stock required for the Canadian Pacific Railway, and also specifications and drawings for the water service on that road.

Upon the completion of construction on the Canadian Pacific Railway, in 1881, and the turning over of the line to the operating company, Mr. Blackwell went to Roanoke, Virginia, as Superintendent of Motive Power of the Norfolk and Western and the Shenandoah Valley Railroads. The Roanoke shops were constructed and equipped according to the plans and specifications prepared by him. The building and equipping of these shops occurred at the time when modern shop practice was just developing, when heavier engines and cars were just

* Memoir prepared by Walter S. Newhall, Esq.

arriving, and when the locomotive and car equipment of it was only dimly foreshadowed, but dreamed of; and yet the Roanoke shops, while they have been extended, remain—as far as their particular buildings are concerned—as Mr. Blackwell planned them, and are well known for their capacity and economical efficiency under present conditions.

Mr. Blackwell left the Norfolk and Western Railroad in 1885, and was engaged on the Union Pacific Railroad for three years, during one year of which he was Manager of the Montana Division.

In 1888 he went to the Central of Georgia Railway as Engineer of the Machinery Department, and remained with that company at Savannah, Georgia, for two years. On account of ill-health he had to come north again, and from 1891 to 1897 was not engaged in railway work; four years of this time he was with the Schoenberger Steel Company, his headquarters being in Pittsburg.

He again entered railroad service at Toledo in 1897 as a special Mechanical and Civil Engineer in the office of the Receivers of the Wheeling and Lake Erie Railroad, remaining with this company after its reorganization, and becoming Principal Assistant Engineer subsequent to August, 1900. During the time he was engaged on the Wheeling and Lake Erie Railroad he made many investigations and reports on that and other properties. In 1903 Mr. Blackwell was tendered the position of Special Assistant to the Chief Engineer of the Wabash Railroad, and entered the service of that company on January 1st, 1904, where he remained for two years.

During the last six years of Mr. Blackwell's life the writer of this memoir was fortunate in knowing him intimately, both socially and professionally, and formed a strong attachment for him. Accurate, methodical, resourceful, with a keen mind for detail and a fund of information acquired by long and varied experience, both as a Mechanical and Civil Engineer, he was especially well adapted to fill the confidential positions which he occupied during the last eight or ten years of his life.

Loyal, kind, and generous, a student of the times, both past and present, he was a charming companion. Born a gentleman, he remained one to the end.

During the last year of his life his health failed rapidly, and he died of Bright's disease, at Cincinnati, on December 29th, 1906.

On December 27th, 1878, Mr. Blackwell was married to Emily, only daughter of Edward B. Chandler, Esq., Barrister, of The Grange, Moncton, New Brunswick, and granddaughter of The Honorable Edward Barron Chandler, Commissioner of Railways, and Governor of the Province of New Brunswick. Mrs. Blackwell and three sons, Thomas Everette, Hubert Charles, and John Buckland, survive him.

Charles Blackwell was elected a Member of the American Society

of Civil Engineers on September 7th, 1881. He was also an Associate Member of The Institution of Civil Engineers of Great Britain; an Honorary Member of the American Railway Master Mechanics Association; and a Member of the Master Car Builders' Association.

SYLVANUS THAYER ABERT, M. Am. Soc. C. E.*

Died August 11th, 1903.

Sylvanus Thayer Abert was born on July 22d, 1828. He was a son of the late John James Abert,† Hon. M. Am. Soc. C. E., Chief of Topographical Engineers, United States Army, and great grandson of Colonel Timothy Matlack, whose Quaker ancestry settled in New Jersey in 1677. Colonel Matlack served during the Revolutionary War as Colonel of Militia from 1775 to 1777; Deputy to the State Conference in 1776; Delegate to the Continental Congress in 1780-81; and as Secretary to the Council of State, and Master of the Rolls, in 1781. He died in Philadelphia in 1829.

Mr. Abert was graduated from Princeton College in 1848, and, as a rodman, he commenced his first engineering work upon the extension of the James River and the Kanawha Canal, then terminating at Lynchburg, Virginia. This canal was designed to connect tidewater at Richmond, Virginia, with the Ohio River, by way of the Kanawha, but was never completed beyond Buchanan, Virginia. Between Richmond and Lynchburg it formed the main line of travel and traffic. The only railroad in Virginia at that time connected Richmond with Fredericksburg, with branches to Acquia Creek and Quantico. The route thence to Washington was by steamer on the Potomac. An account—an amusing travesty—of a journey, made in 1842, from Potomac Creek to Fredericksburg may be found in Dickens' "Notes on America."

In 1849 Mr. Abert was called to Washington to make a survey of the Potomac between the aqueduct over the river at Georgetown and the Long Bridge. He prepared a chart of the river, and recommended the removal of parts of the bridge and the substitution of longer spans.

In 1850 he surveyed the canal which enters the Eastern Branch near the Arsenal, and recommended connecting it with the Chesapeake and Ohio Canal, then extending into Washington on the north side of the Smithsonian grounds.

He made a survey of Cape Vincent Harbor, New York, in 1852, and recommended a breakwater. Two years later he surveyed Tar River, North Carolina, and the construction of the lock and dam there was commenced. In 1855 he made a survey of Beaufort Harbor, North Carolina.

* Prepared by the Secretary from notes furnished by Mr. Abert in 1897.

† A memoir of John James Abert, Hon. M. Am. Soc. C. E., is printed in *Proceedings*, Am. Soc. C. E., Vol. XIX, p. 88.

Mr. Abert's interesting report of the survey of New River Inlet, about 40 miles northeast of Wilmington, North Carolina, in 1856, attracted the attention of Professor A. D. Bache, of the United States Coast Survey. The formation at the mouth of New River received careful study. The position of the delta, built within the coast line by storms, is the reverse of the delta of the Mississippi, which, lying without and beyond the coast line, extends its channels to the Gulf of Mexico, like the outstretched fingers of the hand. Formed by silt brought down by the Mississippi, it diverges seaward; the delta of New River, formed by sand brought in by the ocean storms, diverges landward; but, whether extending landward or seaward, each delta exhibits the same anastomising character, in obedience to the dominating force. In New River the storm force dominates the ebb and the fluvial. The hindrance of the ebb was made apparent by conditions observed during the survey. The tide, passing up the channel, and being detained in the bay above, left an unexpended head of water, where the flood again set inward. To improve the channel, a new relation of forces was necessary, in order to increase the volume of outflowing water; and, to attain this, Mr. Abert proposed deepening and widening the channel, following an easy curvature; he also proposed the fixation of the banks by the use of stones and fascines.

The value of the sounds of Carolina as channels for interior navigation has long attracted the attention of engineers. Part of Mr. Abert's report was devoted to the importance of improving these sounds for coastwise trade and for the transportation of heavy guns and material of war. With the exception of a distance of about 244 nautical miles (between Beaufort, North Carolina, and Charleston, South Carolina), interior navigation, without interruption, extends from Norfolk to Fernandina, a distance of about 1 745 nautical miles. A Government torpedo-boat has safely made the passage through inland channels and by way of Romney Marshes, from Charleston to Fernandina, and a comparatively small amount of excavation would make this channel navigable for war vessels of the same size as the *Amphitrite*. Between Appalachicola and Lake Pontchartrain, by connecting the deep sounds along the coast, the route could be continued to New Orleans.

Northward from Beaufort, North Carolina, an uninterrupted channel exists, by way of bays and canals, as far as New York, and thence by way of the Erie Canal to Lake Erie. The Mississippi can then be reached *via* Chicago, by way of the Illinois and Michigan Canal, thus completing the connection between the Sounds of Carolina and the Mississippi River.

Mr. Abert's report was published in *The Wilmington Journal* (Wilmington, North Carolina), on April 23d, 1856. It may be interesting to note that at this period the Southern States conducted pub-

lic improvements within their borders, and many of them appointed a State Engineer to direct all public works.

In 1857 Mr. Abert was employed as Assistant Engineer on the construction of Fort Delaware, on Pea Patch Island, in the Delaware River, about 40 miles below Philadelphia. This was a casemated work, founded on piles and surrounded by a wet-ditch. Its embrasures were provided with wrought-iron shutters, and it was believed to be impregnable to the artillery of that day.

In 1858 Mr. Abert was ordered to the Warrenton Navy Yard, Florida, and placed in charge of the buildings, works, and ground within the Naval Reservation. The works within the reservation—about 7 miles from Pensacola—were varied and interesting. Mr. Abert built a foundry for heavy castings; constructed 200 ft. of sea wall in 30 ft. of water, by using a diving bell; built a machine shop for the repair of ships; submitted plans for a ship house and launching ship; and prepared plans for a ship basin and graving dock, which were approved by a Board of Engineers appointed by the Secretary of the Navy. The foundation of the dock presented especial difficulties. The yard occupies a tract of sandy soil about 3 ft. above the level of the bay. Borings revealed a stratum of clay 40 ft. below the surface, and another stratum was found about 40 ft. lower. It was evident that the dock would have to be built in water. The plan proposed was as follows:

After dredging the entire area, piles were to be driven at not less than 3 ft. from center to center and then sawed off. For the bottom and side walls, concrete was to be deposited from staging—largely floating staging. After closing the outer end of this concrete box temporarily, the bottom and sides were to be finished with heavy granite facing. A wrought-iron floating gate was designed to close the dock when in use. These plans are now in the Bureau of Yards and Docks at Washington.

Mr. Abert was interested in the Bay of Pensacola, and wrote an official letter recommending Pensacola Harbor as the site of a National dockyard and arsenal. A fleet can find anchorage in its waters, and there are 22½ ft. of water on its bar at mean low water. It is connected by rail with Montgomery, Alabama, and the interior of the country, and the Gulf of Mexico does not contain a better harbor.

There was a general suspension of public improvement works at the beginning of the Civil War, and Mr. Abert reported for duty to the Chief Engineer of Bank's Division, at Frederick City, Maryland, in December, 1861. His services in the campaign in the Valley of the Shenandoah are mentioned in the "Personal Recollections of the War," by General David H. Strother (Porte Crayon), published in *Harper's Monthly,* in March, 1867.

Mr. Abert established a flying bridge at Williamsport, Maryland, upon which the retreating army passed over the Potomac. In 1862

he was at Warrenton Junction, Virginia. He was in Nashville when Hood was defeated, and built Fort Garasche, north of the city and overlooking the Cumberland. He served in the campaign before Petersburg, and was with Meade's Army, under orders of Major Michler, of Meade's engineer staff, until the surrender at Appomattox on April 9th, 1865.*

In 1865 and 1866 Mr. Abert was one of a party of engineers called by the United States of Colombia to make surveys of certain localities and to prepare plans of improvement. The party left New York on December 11th, 1865, for Aspinwall, and, after a short visit to Panama, they returned to Aspinwall and embarked in an English steamer for Santa Martha. At this point work began on December 29th.

The surveys and plans of improvement were made for the following localities:

First.—For connecting by rail the Town of Santa Martha with the Town of Cienega, on the delta of the Magdalena.

Second.—For improving the channel through *canos* of the delta, between Cienega and Barranquilla.

Third.—To survey "the Canal de la Pina and *cienigas* (lakes) and *canos* (channels) through which a navigable route can be made from Barranquilla, on the Magdalena, to Sabanilla, the seaport at the mouth." This canal was "to be of such dimensions as to admit at all seasons the passage of the largest steamers navigating the Magdalena."

Fourth.—The next work was at the Island of Margarita, on the Magdalena, about 140 miles above Barranquilla. This island, of great beauty and fertility, is not less than 40 miles in length. The course of the river had been diverted by a freshet from the right side of the island where it flowed past the flourishing city of Monpox—noted for its "dulces," and famous for its ornaments of gold-wire work—to the left side where it passed the site of the insignificant town of Manganguy. Here were held annual fairs, frequented by merchants of Barranquilla, who readily disposed of all their wares to the natives from the surrounding country. Many of these merchants were natives of Bremen and Hamburg. The Monposians asked the engineers to convert the river to its orthodox course. All that was needed for this object was a jetty.

Fifth.—A reconnaissance was made and a map prepared of the Magdalena from Honda (head of navigation) to Barranquilla, a distance of about 525 miles.

The party returned to New York during the latter part of May, 1866. A revolution preceded the arrival of the engineers in Colombia, another followed soon after their return—the chronic condition of this interesting country.

* Mr. Abert's services are mentioned in somewhat more detail in the statement prepared by him for the Society of the Army of the Potomac.

In 1867 Mr. Abert was in charge of repairs at Fort Foote, on the Maryland side of the Potomac, about a mile below Alexandria.

Mr. Abert's next duty (1869) brought up the question of the connection of the Great Lakes with the Mississippi. He was charged with the survey of the Illinois River from La Salle to its mouth at Grafton. The collection of data—of little interest to the general reader—is an essential object in every survey; the following facts are taken from Mr. Abert's report:

The distance from La Salle to Chicago, by way of the river and the Illinois and Michigan Canal, is	99	miles.
From La Salle to Grafton is..............	223	"
From Chicago to Grafton is...............	322	"

The Illinois and Michigan Canal connects Chicago with the Illinois River. The average fall of the river below La Salle is 0.15 ft. per mile, and the entire fall is 29.6 ft.

Mr. Abert submitted an estimate for an improvement by dredging, and also by locks and dams, and pointed out the importance of this route as a navigable connection between the Lakes and the Mississippi. In his report he says:

"Its real importance can be estimated by regarding it as completing a system of water communication between the East and the West, of which the Erie Canal constitutes an important part."

Under the heading "Lake Michigan as a Reservoir," he considers the importance to navigation of the lake as a feeder to the Illinois at low water. The report states:

"The close of the season did not permit a special examination or survey with a view to the complete solution of this question. Facts and theoretical deductions are herein presented, sufficient to indicate the course of examination to be pursued, in order to solve the problem."

Taking the discharge at Hennepin as a basis, and a width of channel of 350 ft., with a velocity of a little more than one mile per hour, a depth of not less than 8 ft. could be given on all bars during the low-water period, which prevails from 60 to 90 days.*

This project was not approved, and in 1868 was declared "impracticable at any reasonable cost."†

The City of Chicago, unaided by Government, has solved the problem of constructing a ship canal. Mr. Abert wrote, in 1897:

"The year 1898 will see the completion of this stupendous work, which will turn the waters of the Great Lakes into the Mississippi."

* Ex. Doc. 16, 40th Cong., 1st Sess., House of Reps. Also Reports of Chief of Engrs., 1868, pp. 445-449.

† Ex. Doc. 116, 40th Cong., 2d Sess., House of Reps.

A writer observes:

"The solution of the problem of disposing of the city sewage has rendered practicable one of the boldest schemes of improvement of internal navigation which has ever been entertained by engineers. When completed, this canal will have a width of 162 ft., a depth of 25 ft., and a length of about 35 miles. Its maximum flow will be about 600 000 cu. yd. per min., and will increase the Illinois eighteen times in the upper part, twelve times at the mouth at low water, and about 25% at St. Louis, as estimated. For details of this remarkable work the reader is referred to the reports of the engineer, in which he will find an account of the machinery used, the channelers, drills, hoisters, cantilever lifts, and dredges, and statements of the value, kind, and quantity of the work done by them. Thirty millions of dollars will be expended before the final completion of the work, if anything can be called final to a people so energetic and liberal as the citizens of Chicago."

In 1869 Mr. Abert was charged with the survey of the Arkansas River, from Fort Gibson, on the Neosho, in Indian Territory, to its mouth, in the Mississippi. The party was recruited in Cincinnati and started in January, 1869. The steam dredge *Octavia* towed the survey boat to Memphis; thence it was towed to Little Rock by a river steamer, and another steamer conveyed it to Fort Gibson, which was reached on February 7th. On the morning after arrival, one of the party, who had been ailing for some days, was pronounced by the surgeon of Fort Gibson to have confluent smallpox. There were no railroads in Arkansas at that time. Without medical aid, and accompanied by threats of the Indians, the survey began. Five sick men, quarantined in camp, were transported from place to place as the survey advanced. One man died, and was buried on the bank of the river.

The following data are gathered from the report: The distance from Fort Gibson to Little Rock is 289½ miles; the fall is about 242½ ft. Discharge measurements, about 30 miles apart, were taken according to the method of Humphreys and Abbot. Careful record was made of the geology and products of the valley. High water prevailing between January and July, no low-water survey of the bars was practicable. For a channel so variable in its course, and so changeable in the depth and position of its bars, any low-water survey would have been of small value until certain important and preliminary work had been completed. Large tracts of river front are washed away during every freshet, and acres of valuable cotton land are annually destroyed by the current. Therefore, no satisfactory estimate for the improvement of the bars can be made until the banks have been fixed. A small amount of work was recommended at but four localities.

The general conclusion stated in the report was:

"That the first object of improvement should be to give permanency to the banks by protecting them from the abrasion of the current."

The regimen of the river would be established by this means, and the alveus of the stream could then be permanently improved.

Maps and diagrams accompany the report, and profiles and cross-sections, of velocities and oscillations, relating to the hydraulics of the river, are fully represented. The survey* was completed in July, 1869.

In 1871 Mr. Abert was engaged on the survey of the Cumberland River, in Kentucky and Tennessee, and the following facts are gleaned from his report:

From the Great Falls, in Pulaski County, Kentucky, to its mouth, the river is 595 miles long. The Great Falls have a vertical descent of 56 ft. The scenery, as far as Point Burnside, is wild and picturesque. At the rapids the rocks rise in vertical escarpments several hundred feet, and the water flows in a thin sheet over the horizontal stratum of limestone, left bare at low water. Here is a geologist's paradise, for myriads of encrinites are entombed in the rock. From Point Burnside to Nashville the distance is 326½ miles, and the descent 232 ft. at low water. From Nashville to the mouth the distance is 92 miles, and the descent 79 ft.—where the river enters the Ohio, about 73 miles above Cairo.

The obstructions to navigation were:

1.—Overhanging trees;
2.—Ledges of rock;
3.—Bars composed of the debris of bluffs;
4.—Bars of gravel and ferruginous sand;
5.—Obstructions in the lower river, such as sunken wrecks—the remains of the war.

Below Point Burnside the method of improvement consisted chiefly in contracting the stream at designated points.

Under the heading, "Resources" the report gives a brief description of the geology and a short history of the coal mines of Pulaski County and of Poplar Mountain. The first mines are above Point Burnside; the Poplar Mountain mine is 58 miles lower down and about 268 miles above Nashville.

The Tennessee Rolling Mills, below Nashville, are at the point where the river passes again into Kentucky. A fine quality of boiler iron is made from the brown hematite found buried on the banks of the river in the form of geodes from 1 to 2 ft. in diameter. These geodes often contain fossil crinoids and crystals of lime. The plates made from this ore are used extensively in the manufacture of the boilers of boats on western waters.

The advantage of a ship canal across the Isthmus connecting Central and South America has long attracted the attention of scientists

* Ex. Doc. 295, 41st Cong. 2d Session.

and engineers. Humboldt devotes several pages to its consideration. Hughes' favorable opinion called public attention to Panama, and Strain's expedition across Darien was led to misfortune by the mythical account of Gisborne. Michler's able survey of Atrato, and Childs' clever report on Nicaragua gave hope of a feasible route; but all these surveys and reports leave the mind in doubt as to which route should be selected for a ship canal. Each possessed advantages and disadvantages. Upon some lines, harbors on the Pacific were separated from harbors on the Gulf by an insurmountable barrier, or one that could only be penetrated by a costly tunnel. On other lines, while the divide opposed no difficult obstruction, harbors are wanting at the termini. To form an intelligent opinion, Mr. Abert attempted to bring together all the information to be found in reports relating to this subject. While in Cincinnati, in 1872, he published a pamphlet having the following title: "Notes, Historical and Statistical, upon the Projected Routes for an Interoceanic Ship Canal between the Atlantic and Pacific Oceans, in which is included a short Account of the Character and Influence of the Canal of Suez, and the Probable Effects upon the Commerce of the World, of the Two Canals, Regarded either as Rivals, or as Parts of one System of Interoceanic Travel."

This pamphlet* was given a wide publication. It was printed by Murat Halsted in a broadside of *The Cincinnati Commercial.* It was favorably commented on by R. J. Walker, ex-Secretary of the Treasury, by W. H. Seward, Secretary of State; by Nathan Appleton; by the editor of the *Journal* of the Franklin Institute; and by *The Nation,* of New York. Though valuable at the time of publication, its information has been superseded by later surveys, and by the work done on the Nicaragua and Panama Canals; but a navigable way across the Isthmus is still an unsolved problem.

In 1873 Mr. Abert was called to important duty upon the Atlantic seaboard. By order of the Secretary of War, he was placed in charge of a geographical division beginning at Washington, D. C., and terminating at Wilmington, North Carolina. His annual reports relate to the surveys and improvements of rivers and harbors in Maryland, Virginia, and North Carolina. Among the more important are those relating to Norfolk Harbor, Elizabeth, York, Rappahannock, and Roanoke Rivers, the reclamation of the flats at Washington, and the survey of an inland line of navigation between Norfolk and Wilmington.

The plan for the reclamation of the Potomac flats was submitted to a Board of Engineers, appointed by General A. A. Humphreys. The problem was complicated with the sanitary conditions, caused by a large flat extending in front of the city. Beginning with a width of ½ mile at Georgetown, the river widens to 1 mile at the Long Bridge,

* Published by R. W. Carroll and Company, Cincinnati, 1872.

about 3 miles lower down, and the flats were traversed by two channels (in 1790 by three channels). It was proposed to reclaim this area, near the Washington side, by a deposit raised above the level of the highest water, and conforming in outline to the hydrographic curves. The area covered by the reclamation was about 700 acres—an addition to the city largely exceeding in value the money to be expended upon it.

The canal to connect the waters of Norfolk Harbor with the Cape Fear River at Wilmington is so important that it deserves some notice. It may be described briefly under three heads:

1.—An inland navigation, near the coast, and chiefly by way of the sounds;

2.—Physical features of the coast;

3.—Historical notes and old maps.

In relation to the canal, estimates are submitted, but Mr. Abert recommends that nothing be done until further examinations have been made. Other routes are mentioned, and an examination of each is regarded as necessary before the problem of location can be solved. Description is given of the Kearney route, and the report of Colonel Kearney is printed in the appendix. Under the headings, "Physical Description" and "Coast Line," quotations are made from the following maps: Hariot's, 1585; Lauson, 1708; Wimble, 1738; Mouzin, 1775; Atlantic Neptune, 1780; Lewis, 1795; United States Coast Survey, 1875. Copies of these maps accompany the report. A study of them exhibits interesting changes in the coast line. Attention is called to the progressive closing of the inlets, and to the southward and southwestward movement of the sand drives.

Under the heading "Changes of the Inlets," comparison is made of the condition at the time of survey and the condition represented on the map of Hariot (1584). Comparison is also made with the statement of Colonel William Byrd, Commissioner on the part of Virginia and North Carolina. Colonel Byrd's observations, made in 1713, are contained in the famous Westover manuscript. The first accurate mapping of the coast line will be found in the charts of the Coast Survey. With this aid we can trace the rate of "Hatteras' advancing foot," and measure the retreat of the coast line between New River Inlet and Masonborough, an inlet near Wilmington.

Five expeditions were sent out by Sir Walter Raleigh, between 1584 and 1590, to the coast of Virginia—now North Carolina. Extracts are given from voyages and travels, published by De Bry Brothers, in Frankfort in 1590, and from Hakluyt's Collection "reprinted in London in 1600." These extracts are accompanied by comments in which Mr. Abert endeavors to follow the steps of the exploring party after landing at Roanoke Island. No permanent settlement

was made by the five expeditions sent by Sir Walter to the coast of Virginia, but the writers mentioned supply valuable matter to one who wishes to study the changes in the coast.

Included in the appendix is an interesting letter from Colonel Marshall Parks, President of the Albemarle and Chesapeake Canal, also one from Mr. McAlpin C. Engs. Tables of statistics of trade are added. If not the most interesting, this report includes much valuable matter. Other reports by Mr. Abert, on the rivers and harbors of Virginia, Maryland, and North Carolina, will be found in the Reports of the Chief of Engineers between the years 1873 and 1890.

Mr. Abert was elected a Member of the American Society of Civil Engineers on September 21st, 1870.

LOUIS FREDERIC GUSTAVE BOUSCAREN, M. Am. Soc. C. E.*

Died November 6th, 1904.

Louis Frederic Gustave Bouscaren was born on the Island of Guadeloupe, on August 26th, 1840. Both his parents were of old West Indian families of French descent, his great-grandfather having been awarded a large part of the Island of Guadeloupe, with the title of Marquis, by the French Government for distinguished services rendered by him as a member of the French Military Engineer Corps.

In 1850 the parents of Mr. Bouscaren, who were quite wealthy, came to the United States, settling on a large tract of land which they had purchased in Grant County, Kentucky, a part of which, with the old homestead, is still retained by the family.

Mr. Bouscaren, who was the oldest son of eight children, received his earlier education at home, but at the age of twelve he was sent to St. Xavier's College at Cincinnati, Ohio. Two years later he was sent to France, where he entered the Lycée St. Louis, one of the great Government schools in Paris, remaining there until he was twenty, after which he entered L'Ecole Centrale des Arts et Manufactures, from which he was graduated with high honors, in 1863, as "Ingénieur des Arts et Manufactures."

His first employment, after his return, was as Draftsman in the office of S. Hannaford and Sons, leading architects in Cincinnati, and, later, while awaiting an opportunity to become connected with outside engineering work, with the firm of Lane and Bodley, manufacturers of mill machinery and engines.

In 1865 Mr. Bouscaren was appointed Assistant Engineer of Maintenance-of-Way on the Ohio and Mississippi Railroad, under the late Thomas D. Lovett, M. Am. Soc. C. E., Chief Engineer, and later un-

* Memoir prepared by G. H. Benzenberg, President, Am. Soc. C. E.

der the late E. C. Rice, M. Am. Soc. C. E., who succeeded Mr. Lovett. He served under these two engineers in various positions for the next 11 or 12 years In 1863-69, as Assistant to Mr. Rice, he made the preliminary and location surveys, and later was in charge of construction of the St. Louis, Vandalia and Terre Haute Railroad. From 1869 to 1872 he served as Principal Assistant to Mr. Rice on the St. Louis and South Eastern Railroad, at the same time acting as Chief Engineer of the O'Fallon and Belleville Railroad. In 1872-73 he was Principal Assistant on the Cairo and Vincennes Railroad. In these several positions Mr. Bouscaren showed a marked faculty for details, which, together with his close application and skill, led to his being entrusted with greater responsibilities.

In 1873, Mr. Lovett, then Principal Engineer of the Cincinnati Southern Railway, engaged him to prepare the specifications for, and to take charge of the construction of, the great railway bridge for this road over the Ohio River at Cincinnati. Immediately following this he was appointed First Assistant Engineer, Department of Construction, of the Cincinnati Southern Railway, which position he held until late in 1876, when, upon the resignation of Mr. Lovett, he succeeded him as Consulting and Principal Engineer, and completed the construction of the road.

In the preparation of the plans and specifications for this bridge, which was to embody, at that time, the longest truss span in the world, Mr. Bouscaren entered upon a comprehensive series of tension and compression tests of full-sized bridge members and worked out new formulas based upon the results of these tests. He also introduced in his specifications new forms for considering concentrated loads, and in many ways advanced the requirements for bridge construction, especially in the matter of details, so that his specifications for the many bridges which he, as Principal Assistant and later as Chief Engineer, built for the Cincinnati Southern, were accepted as models by many engineers.

Among many bridges, the noted Kentucky River Bridge may be mentioned as the first great cantilever bridge in this country. This bridge was built by the late C. Shaler Smith, M. Am. Soc. C. E., and was first designed to be a continuous bridge, but Mr. Bouscaren changed this design, fixing the points of contraflexure by cutting the lower chords, enclosing the ends in loose sleeves.

The line of the Cincinnati Southern Railway runs through very hilly and mountainous country, and the many difficulties natural to such a location were successfully overcome by Mr. Bouscaren's engineering skill. The construction included some twenty-seven tunnels, the most important of which was the King's Mountain Tunnel, more than 4 000 ft. long.

In 1881, when the Cincinnati Southern Railway was leased by the

Erlanger Syndicate, Mr. Bouscaren was made Consulting and Chief Engineer of the entire railroad system controlled and operated by this Syndicate. In this capacity he constructed the New Orleans and North Eastern Railroad, and completed the construction of the Vicksburg, Shreveport and Pacific Railroad. He also did a large amount of reconstruction work on the Alabama Great Southern and on the Vicksburg and Meridian Railroad. In connection with the New Orleans and North Eastern Railroad, he constructed a pile trestle, 21 miles in length, where the railroad crosses the Lake Pontchartrain marshes. All the timber used in this trestle was creosoted, for which purpose he designed and had built the most extensive creosoting plant in the country at that time.

In 1886 Mr. Bouscaren resigned his position as Chief Engineer, and opened an office in Cincinnati as Consulting Engineer. The reputation which he had established as a careful, capable and conscientious engineer secured for him a considerable amount and variety of work. He was engaged in the construction of a number of bridges across the Ohio River, among them the Central Bridge between Cincinnati and Newport, which he designed, and the Chesapeake and Ohio Railroad Bridge. He also had charge of the strengthening of the cables of the suspension bridge between Cincinnati and Covington, and designed and constructed the Fourth Street Bridge over the Licking River in Covington, Ky. He was a member of the Commission appointed by President Cleveland to examine into and report upon the best plan to bridge the North River.

From 1887 to 1891 Mr. Bouscaren was Chief Engineer for, and built, the Covington, Ky., Water-works; he also built the Norwood Water-works. In July, 1896, the Board of Trustees, "Commissioners of Water-works," appointed him Chief Engineer of the new works which were to be constructed for the City of Cincinnati, in which work, Charles Hermany, Past-President, Am. Soc. C. E., and the writer were associated with him as Consulting Engineers. To this work he devoted his entire time and his best skill and energy up to the day of his death, and so far as the same was planned by him, it will stand as a lasting monument of his ability and eminence as an engineer.

Into all of his work Mr. Bouscaren introduced an individuality based upon his independence of research and conclusion, which very often led him in advance of contemporaneous practice. He was a close student and a constant reader and had acquired a very large library of scientific and professional works. His plans and specifications were always clear, comprehensive and explicit, and he would never allow a contractor to swerve or deviate in the least from a full compliance with every obligation of the contract and specifications. He was firm, strict and insistent, yet at no time unjust and unfair.

Honesty of purpose and integrity were leading characteristics in all his business transactions.

Socially Mr. Bouscaren was of a delightful and generous disposition, always unselfish and unassuming, and ever courteous in his demeanor toward his assistants and co-laborers. Being a devout member of his Church, he was also liberal in aiding her charities.

On April 18th, 1876, Mr. Bouscaren married Miss Helen Seymor Lincoln, daughter of Timothy D. Lincoln, a distinguished lawyer of Cincinnati. Twenty-five years of happy home life followed this union, which grew to a family circle of three sons and two daughters. Mrs. Bouscaren's death, in July, 1901, was a severe blow from which he never fully recovered, especially as his children shortly after left their home to attend school, the oldest son being at the Massachusetts Institute of Technology, the second son studying law at Yale, while the daughters attended school in the Convent at Washington, D. C.

Shortly after attending the Annual Meeting of the American Society of Civil Engineers, in January, 1903, Mr. Bouscaren was attacked with severe pains and internal hemorrhages which compelled him to avoid much walking or exercise, and which necessitated his remaining much of the time either at his home or at the hospital, where he underwent two painful operations—which gave him little relief—followed by long periods of suffering, during which he displayed wonderful patience and fortitude, regretting only that he could not oversee and finish the work he had undertaken. Despite all the efforts of eminent surgeons and physicians, he became so weak that on November 6th, 1904, surrounded by his children, his brother and sisters, he quietly passed away.

Thus ended an active, sincere and useful life, full of good deeds and creditable work, whose record is that of an honest, upright, capable and eminent engineer.

On April 7th, 1875, Mr. Bouscaren was elected a Member of the American Society of Civil Engineers. He served as a Member of the Board of Direction in 1881; and held the office of Vice-President at the time of his death. He also served on a number of special and other committees, and was a frequent contributor to the professional papers and discussions.

In June, 1880, he was elected a Member of the Société des Ingénieurs Civils de France, and, on December 7th, a Member of the Institution of Civil Engineers of Great Britain.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852.)

VOL. XXXIII. No. 8.

OCTOBER, 1907.

Edited by the Secretary, under the direction of the Committee on Publications.

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CONTENTS.

NEW YORK 1907.

Entered according to Act of Congress, by the American Society of Civil Engineers, in the office of the Librarian of Congress, at Washington.

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BERNARD R. GREEN.

Term expires January, 1909:
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JOHN A. OCKERSON.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOSEPH M. KNAP.

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Term expires January, 1908:
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ON STATUS OF METRIC SYSTEM: Stacy B. Opdyke, Jr., John Waterhouse, D. A. Molitor.

ON ENGINEERING EDUCATION:—Desmond FitzGerald, Benjamin M. Harrod, Onward Bates, D. W. Mead, Charles Hansel.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER.......................5918 Columbus.
CABLE ADDRESS........................"Ceas, New York."

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

September 18th, 1907.—The meeting was called to order at 8.30 P. M.; Director A. L. Bowman in the chair; Chas. Warren Hunt, Secretary; and present, also, 95 members and 21 guests.

A paper by G. L. Robinson, Assoc. M. Am. Soc. C. E., entitled "A Description of the Recently Installed Sewage Disposal Works for the Village of Ballston Spa, New York," was presented by the author, and discussed by G. S. Webster, M. Am. Soc. C. E.

The Secretary announced the following deaths:

ARTHUR HENRY BIRKS, elected Junior, April 5th, 1904; Associate Member, November 7th, 1906; died August 29th, 1907.

GEORGE WASHINGTON PLYMPTON, elected Member, January 29th, 1868; died September 11th, 1907.

Adjourned.

October 2d, 1907.—The meeting was called to order at 8.30 P. M.; Director Allen Hazen in the chair; Chas. Warren Hunt, Secretary; and present, also, 190 members and 30 guests.

The minutes of the meeting of September 4th, 1907, were adopted as printed in *Proceedings* for September, 1907.

A paper by D. W. Krellwitz, Jun. Am. Soc. C. E., entitled "Reinforced Concrete Towers," was presented by the Secretary.

A paper by Chester Wason Smith, Assoc. M. Am. Soc. C. E., entitled "Reinforced Concrete Pipe for Carrying Water Under Pressure," was presented by the Secretary, who also read communications on the subject by Messrs. F. Teichman and J. R. Worcester. The paper was discussed by Messrs. R. W. Lesley and Thomas H. Wiggin.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Charles Chapman Anthony, Philadelphia, Pa.
Reuben Edwin Bakenhus, Newport, R. I.
B J Dalton, Lawrence, Kans.
William Thomas Dougan, New York City.
Homer Johnston Gault, Selden Station, N. Mex.
George Higgins, Melbourne, Victoria, Australia.
Henry F Jonas, Houston, Tex.
Willard Kent, Narragansett Pier, R. I.
Walstan Emile Knobloch, New Orleans, La.
Adolph Thomas Kroeber, New York City.
Stephen Arnold Mitchell, Kansas City, Mo.
Eugene Mowlds, Edge Moor, Del.
Joseph Pettus Newell, Portland, Ore.
William Collins Phelps, New York City.
Herbert Leroy Potter, Brooklyn, N. Y.
Henry Atherton Schulze, San Francisco, Cal.
James Shand, Salina Cruz, Oaxaca, Mexico.
Edward Peter Shuman, Vigan, Philippine Islands.
Jesse Baker Snow, New York City.
Edwin Brinton Temple, Philadelphia, Pa.
John Hermon Terry, Philadelphia, Pa.
William Charles Weeks, Spokane, Wash.
Benjamin Emanuel Winslow, San Francisco, Cal.

As Associate Members.

Algernon Brown Alderson, West Hartford, Conn.
Kay Alexander, St. Regis, Mont.
Percival Stevens Baker, Philadelphia, Pa.

John Berger, New York City.
Charles Ernest Beugler, Oakland, Cal.
Edward Elisha Bratton, Philadelphia, Pa.
Harry Frank Cameron, Cebu, Philippine Islands.
George Payson Carver, Beverly, Mass.
Ira Mason Chace, Jr., Tucson, Ariz.
Edward Merriam Chadbourne, San Francisco, Cal.
Robert Lloyd Chamberlaine, Baltimore, Md.
Paul Chipman, Montreal, Que., Canada.
Edward Walter Cunningham, Cleveland, Ohio.
George Jacob Davis, Jr., Madison, Wis.
Harry Whiting Dennis, Niagara Falls, N. Y.
Gotthard Vincent Dieden, Leesville, Va.
Thomas Benson Downer, Mojave, Cal.
Chester Centennial Fisher, Meridian, Idaho.
George Munro Forrest, New York City.
Edward James Fucik, Chicago, Ill.
Joseph Harrington Gandolfo, New York City.
Leon Lincoln Gay, Boise, Idaho.
August Gundersen, Detroit, Mich.
Harry Macy Harps, New York City.
Allan Collins Harrington, Albion, N. Y.
Jay Butler Harris, Los Angeles, Cal.
Newton Fisher Hopkins, Pittsburg, Pa.
Harold Wellington Horne, New York City.
Herbert Frank Howe, Cebu, Philippine Islands.
Hyotaro Inagaki, Taipeh, Formosa, Japan.
Willard Edward Ingram, Chicago, Ill.
Edwin Samuel Johnson, Miami, Fla.
Lorin Acil Keith, Mansfield, Ohio.
Jay Cowden Lathrop, San Francisco, Cal.
Clifford Milton Leonard, Chicago, Ill.
Javier Diaz Lombardo, Necaxa, Puebla, Mexico.
Clarence William Meyers, New York City.
Howard Scott Morse, Glendive, Mont.
Charles Andrew Pohl, Lyons, N. Y.
Sam Graham Porter, Holly, Colo.
Charles Henry Preston, Jr., Waterbury, Conn.
Clinton Leroy Richardson, Atlanta, Ga.
Shigeki Sekiba, Beaver Falls, Pa.
Julian Chatard Smith, Philadelphia, Pa.
Gabriel Roberts Solomon, Atlanta, Ga.
Herbert Harris Starr, New Haven, Conn.
William Lawrie Stevenson, Philadelphia, Pa.
James Wolfe Sussex, Wenatchee, Wash.
Eugene Adams Yates, New York City.

AS ASSOCIATE.

GEORGE NATHAN COLE, New York City.

The Secretary announced:

The transfer of the following candidates by the Board of Direction on October 1st, 1907:

FROM ASSOCIATE MEMBER TO MEMBER.

WILLIAM LOWE BROWN, New York City.
BERTRAM HENRY MAJENDIE HEWETT, New York City.
WILLIAM MAYO VENABLE, Miami, Fla.

The election of the following candidates by the Board of Direction:

AS JUNIORS.

On April 2d, 1907:

NORRIS RAYMOND MACKLEM, Jackson, Mich.

On September 3d, 1907:

WILLIAM GEORGE BROADHURST, New York City.
MATTHEW DETOBIN KELLEY, San Juan, Porto Rico.

On October 1st, 1907:

JAMES MADISON BARKER, Boston, Mass.
SIDNEY RAYMOND BELLOWS, Conimicut, R. I.
HIRAM NELSON BISHOP, Berkeley, Cal.
GEORGE EARLE BURNHAM, Manila, Philippine Islands.
ARTHUR WILLIAM BUSHELL, Manila, Philippine Islands.
HENRY WILLIAM CORP, Providence, R. I.
CLINTON ALONZO CURTIS, Ft. Edward, N. Y.
CHARLES LOUIS DIMMLER, Berkeley, Cal.
ROBERT LESLIE HOLMES, Boyce, La.
HAROLD EDMUND MILLER, Providence, R. I.
JULIO DANIEL MONTERO, Güines, Cuba.
JABEZ CURRY NELSON, Birmingham, Ala.
STEPHEN HENLEY NOYES, Long Island City, N. Y.
EDWIN JAMES POTTER, Bridgeton, R. I.
JOHN KUHN SCOTT, Pittsburg, Pa.
EVERETT HAROLD SWETT, Providence, R. I.
WILLIAM ALBERT YEO, New York City.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

October 1st, 1907.—Past-President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bowman, Christie, Gibbs, Hazen, Hodgdon, Knap, Schneider, Smith, Stearns, and Swensson.

A modification of the form of Ballot List, and a circular to be issued to the Corporate Members with the next list, were adopted.

A resolution of thanks for the hospitality received by the Society in Mexico was adopted and ordered to be suitably engrossed and forwarded to the proper parties.

Applications were considered and other routine business transacted.

Three Associate Members were transferred to the grade of Member, and seventeen candidates for Junior were elected.*

Adjourned.

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* See page 426.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, November 6th, 1907.—8.30 P.M.—Ballots for membership will be canvassed, and a paper entitled "Water Purification at St. Louis, Mo.," by Edward E. Wall, M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for September, 1907.

Wednesday, November 20th, 1907.—8.30 P. M.—A paper entitled "The Reinforced Concrete Work of the McGraw Building," by William H. Burr, M. Am. Soc. C. E., will be presented for discussion at this meeting.

This paper is printed in this number of *Proceedings.*

Wednesday, December 4th, 1907.—8.30 P. M.—Ballots for membership will be canvassed, and a paper entitled "Invar (Nickel-Steel) Tapes on the Measurement of Six Primary Base Lines," by Owen B. French, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings.*

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Society of Engineers, 17 Victoria Street, Westminster, S. W., England.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Civil Engineers' Club of Cleveland, 718 Caxton Building, Cleveland, Ohio.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa.

Engineers' Society of Western Pennsylvania, 803 Fulton Building, Pittsburg, Pa.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

Louisiana Engineering Society, 604 Tulane-Newcomb Building, New Orleans, La.

Engineers' Club of Central Pennsylvania, Corner Second and Walnut Streets, Harrisburg, Pa.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Teknisk Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Société des Ingénieurs Civils de France, 19 Rue Blanche, Paris, France.

Svenska Teknologföreningen, Brunkebergstorg 18, Stockholm, Sweden.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Pacific Northwest Society of Engineers, 617–618 Pioneer Building, Seattle, Wash.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Memphis Engineering Society, Memphis, Tenn.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

The Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Cleveland Institute of Engineers, Middlesbrough, England.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Rochester Engineering Society, Rochester, N. Y.

Brooklyn Engineers' Club, 197 Montague Street, Brooklyn, N. Y.

Montana Society of Engineers, Butte, Montana.

LIST OF NOMINEES FOR THE OFFICES TO BE FILLED AT THE ANNUAL ELECTION, JANUARY 15, 1908.

The following list of nominees for the offices to be filled at the Annual Meeting, January 15th, 1908, received from the Nominating Committee, was presented to the Board of Direction at its meeting on October 1st, 1907. The list has already been mailed to all Corporate Members.

For President, to serve one year:

CHARLES MACDONALD, New York City.

For Vice-Presidents, to serve two years:

GEORGE F. SWAIN, Boston, Mass.
MORDECAI T. ENDICOTT, Washington, D. C.

For Treasurer, to serve one year:

JOSEPH M. KNAP, New York City.

For Directors, to serve three years:

CHARLES L. HARRISON, New York City, representing District No. 1.
GEORGE W. KITTREDGE, New York City, representing District No. 1.
DEXTER BRACKETT, Boston, Mass., representing District No. 2.
GARDNER S. WILLIAMS, Ann Arbor, Mich., representing District No. 3.
HORACE ANDREWS, Albany, N. Y., representing District No. 3.
CHARLES S. CHURCHILL, Roanoke, Va., representing District No. 6.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendix* to the Annual Report of the Board of Direction for the year ending December 31st, 1906, contains a summary of all searches made to that date.

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* *Proceedings*, Vol. XXXIII, p. 20 (January, 1907).

ACCESSIONS TO THE LIBRARY.

(From September 11th to October 7th, 1907.)

DONATIONS.*

RIVER DISCHARGE.

Prepared for the Use of Engineers and Students. By John Clayton Hoyt and Nathan Clifford Grover, Assoc. Members, Am. Soc. C. E. Cloth, 9 x 6 in., illus., 8 + 137 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907. $2.00.

The increase in the development of the water resources of the United States has created a demand for information relative to the flow of streams. Much has been written on the methods of measuring stream flow, but such information is scattered through periodicals and Government reports and is not readily accessible to engineers and students. Text-books also are indefinite in their descriptions, usually stating only general methods. The authors state that, in this book, they have brought together all available information in regard to the best practice in this work. They have added much that is new, such as descriptions of conditions necessary for good gauging stations at which measurements of discharge may be made, either by weir, current meters, floats, or slope; the selection, establishment and maintenance of gauging stations; the details of field work of discharge measurements, and office methods for computing the regimen of flow. It is also stated that the scope of this discussion of surface flow includes methods of measuring and computing stream flow; laws which govern such measurement and the degree of accuracy obtainable; the phenomena which affect the flow of streams; and the uses to which the data are applicable. The Contents are: Introduction; Conditions Affecting Stream Flow; Instruments and Equipment; Velocity-Area Stations; Weir Stations; Discussion and Use of Data; Hydraulic Tables. There is an index of five pages.

THE COPPER MINES OF THE WORLD.

By Walter Harvey Weed. Cloth, 9 x 6 in., illus., 14 + 375 pp. New York and London, Hill Publishing Company, 1907. $4.00.

This book is divided into two parts. In the first part the author gives a general account of copper deposits, their distribution, geologic occurrence, their structural, mineralogical and chemical relations, etc. The second part is a purely descriptive account of the world's most important copper mines, no attempt being made to present the facts concerning the financial aspect of such properties. The Chapter headings are: Distribution of Copper Deposits; Production of Copper; Mineralogy of Copper; Geologic Distribution and Occurrence; Outcrops and Gossan Formation; Genesis of Copper Deposits; Classification of Copper Deposits; Copper Mines of Europe; Copper Deposits of Africa; Copper Deposits of Asia; Copper Mines of Japan; Copper Deposits of Australasia; Copper Mines of South America; Copper Deposits of the West Indies and Central America; Copper Deposits of Canada and New Brunswick; Copper Deposits of Mexico; Copper Deposits of the United States. There is an index of nine pages.

JAHRBUCH FÜR DAS EISENHÜTTENWESEN.

(Ergänzung zu *Stahl und Eisen.*) Ein Bericht über die Fortschritte auf allen Gebieten des Eisenhüttenwesens im Jahre 1904. Im Auftrage des Vereins deutscher Eisenhüttenleute bearbeitet von Otto Vogel. V. Jahrgang. Cloth, 10 x 7 in., illus., 16 + 448 pp. Düsseldorf, A. Bagel, 1907. $2.50.

Like former numbers, this Annual is issued as a supplement to *Stahl und Eisen*. It contains a general review of periodical literature of the metallurgy of iron for 1904, the authorities quoted numbering more than 3 000 as against 2 600 for 1903. Besides the bibliographies, statistics of the iron industry and a review of patent literature are given. The following subjects are indexed: fuels and firing; slags, ores and the various kinds of iron; the working of iron, and its

* Unless otherwise specified, books in this list have been donated by the publisher.

properties; alloys; and testing the material. Abstracts of important articles are given in addition to their sources. The bibliographies are arranged by subject, and the index is divided by subject and author. It is stated by the editor that after this number, the publication of *Jahrbuch für Eisenhüttenwesen* will be discontinued, owing to the fact that a quarterly, *Zeitschriftenschau*, which covers the same ground, has been combined with *Stahl und Eisen*, and issued as a weekly, thereby keeping the subject-matter up to date in a manner not possible in a yearly issue. The Chapter headings are: Allgemeiner Teil; Brennstoffe; Feuerungen; Feuerfestes Material; Schlacken; Erze; Werksanlagen; Roheisenerzeugung; Giessereiwesen; Erzeugung des Schmiedbaren Eisens; Verarbeitung des Schmiedbaren Eisens; Weiterverarbeitung des Eisens; Eigenschaften des Eisens; Legierungen und Verbindungen des Eisens; Materialprüfung.

RECOLLECTIONS OF AN ILL-FATED EXPEDITION

To the Headwaters of the Madeira River in Brazil. By Neville B. Craig. In Coöperation with Members of the Madeira and Mamoré Association of Philadelphia. Cloth, 9 x 6 in., illus., 479 pp. Philadelphia and London, J. B. Lippincott Company, 1907. $4.00 net.

The Madeira and Mamoré Association is composed of men who, in 1878, were sent out to Brazil by the American contractors—P. & T. Collins and Mackie, Scott & Co.—to survey and construct the Madeira and Mamoré Railway around the falls and rapids of the Upper Madeira River. This railway, with the proposed steamship lines, was to form a system of international transportation between the United States and the interior of Bolivia and to open the South American continent to the markets of the world. The enterprise failed by reason of litigation which ruined the contracting firms. At a reunion of the Association in 1903, it was determined to have a history of the enterprise written by a member of the expedition. An instalment of the proposed history was issued in pamphlet form at each subsequent reunion of the Association. This method of presentation being found to be impracticable by reason of the constant necessary amplification and correction of the printed parts, the present publication in book form was determined upon, and this the author presents as "a true history of one of the most remarkable enterprises ever undertaken by Americans on foreign soil."

SPIRALS FOR STREET RAILWAY CURVES

And Easement Curves for Street Railway Branch-Offs: Complete Formulas and Tables. Leather, 7 x 4 in., illus., 96 pp. Steelton, Pa., The Pennsylvania Steel Company, Frog and Switch Department, copyright 1906.

The spiral system, as presented in this book, is that used by the Pennsylvania Steel Company. It consists of a transition formed of arcs of diminishing radii and is calculated upon the center line of track. The first seven pages of the book are devoted to various problems, the solution of which, as stated in the preface, presents sufficient information to enable any data required for the laying out or construction of track to be readily secured. The remainder of the book relates to: Standard Spirals, The Pennsylvania Steel Co.; Center Line Data; Tables Giving Elements of Spirals for Inner Gage Line Lengths of Rails and Tie Rod Spacing for Various Gages; Middle Ordinates for 10-Foot Chords; Wheel Contours. At the end of the book are illustrations of specialties in frogs, switches and switchstands.

Gifts have also been received from the following:

Am. Ry. Master Mechanics' Assoc. 1 bound vol.
Am. Steel & Wire Co. 1 bound vol.
Boston & Maine R. R. Co. 1 pam.
Brown, C. C. 1 pam.
Canada-Dept. of Marine and Fisheries. 4 vol.
Chicago, Ill.-City Statistician. 4 pam.
Chicago & Northwestern Ry. Co. 1 pam.
Clarke, D. D. 1 bound vol.
Cleveland, Ohio-Water-Works Div., Board of Public Service. 1 vol.
Denver & Rio Grande R. R. Co. 1 pam.
Engineering Record. 2 bound vol.
Eng. Standards Comm. 3 pam.
Engrs.' Soc. of Western Pennsylvania. 1 pam.
Exploration Co., Limited. 1 pam.
Fisk & Robinson. 1 pam.
Glasgow & South-Western Ry. Co. 1 pam.
Gurley, W. & L. E. 1 bound vol.
Hocking Valley Ry. Co. 1 pam.
Ill.-State Geol. Survey. 1 bound vol.
Indiana-Dept. of Geology and Natural Resources. 1 bound vol.
Indiana Eng. Soc. 1 pam.
Inst. of Marine Engrs. 1 bound vol.
Institution of Civ. Engrs. of Ireland. 1 vol.
Iron and Steel Inst. 1 bound vol.
Italy-Royal Minister of Foreign Affairs. 1 pam.
Ives, H. C. 1 pam.

Jacksonville, Fla.-Trustees for the Waterworks and Impvt. Bonds. 1 pam.
Japan-Imperial Earthquake Investigation Comm. 2 vol.
Kanawha & Mich. Ry. Co. 1 pam.
Liverpool Eng. Soc. 1 pam.
Madras, India-Public Works Dept. 1 pam.
Maine Central R. R. Co. 1 pam.
Mexico-Direccion Gen. de Obras Publicas. 1 vol.
Mich. Coll. of Mines. 1 vol.
Middletown, Conn.-Board of Water Commrs. 1 pam.
Minneapolis, St. Paul & Sault Ste. Marie Ry. Co. 1 pam.
Nashville, Chattanooga & St. Louis Ry. Co. 1 pam.
National Assoc. of Cotton Mfrs. 1 bound vol.
National Fire Protection Assoc. 1 pam.
New South Wales-Chf. Commr. of Govt. Railways. 1 pam.
New York City-Board of Water Supply. 4 pam.
New York City-Dept. of Docks and Ferries. 3 bound vol.
New York City Record. 1 bound vol.
New York, Ontario & Western Ry. Co. 1 pam.
North, E. P. 1 pam.
Ohio-Bureau of Inspection and Supervision of Public Offices. 2 pam.
Ontario, Canada-Bureau of Mines. 2 bound vol.
Osborn, E. E. 1 pam.
Poor's R. R. Manual Co. 1 bound vol.
Rust, C. H. 1 pam.
St. Petersburg Soc. of Civ. Engrs. 4 pam.
Smithsonian Institution. 1 vol.
Somerville, Mass.-City Clerk. 1 bound vol.
Stone & Webster. 1 pam.
Switzerland-Eidgen. Hydrometrische Bureau. 1 pam.
Toledo & Ohio Central Ry. Co. 1 pam.
Toledo, Peoria & Western Ry. Co. 1 pam.
Transvaal-Chf. Engr. of the Rand Water Board. 1 pam.
U. S. Chf. of Div. of Publications, Dept. of Agri. 1 pam.
U. S. Engr. School. 1 pam.
U. S. Forest Service. 2 pam.
U. S. Geol. Survey. 2 pam.
U. S. Interstate Commerce Comm. 18 pam.
U. S. Lake Survey Office. 1 pam.
U. S. Naval War Records Office and Library. 1 pam.
U. S. Office of Public Roads. 2 pam.
Walker, J. W. G. 1 bound vol.
Western Australia-Acting Comm. of Railways. 1 bound vol.
Whitford, N. E. 3 bound vol.
Wilmington, Del.-Water Dept. 1 pam.

BY PURCHASE.

Handbook of the Trees of the Northern States and Canada, East of the Rocky Mountains. Photo-descriptive. By Romeyn Beck Hough. Lowville, N. Y., Published by the Author, 1907.

Irrigation: Its Principles and Practice as a Branch of Engineering. By *Sir* Hanbury Brown. New York, D. Van Nostrand Company, 1907.

Public Health, Volume XXXII, Pts. 1 and 2. Papers and Reports Presented at the Thirty-fourth Annual Meeting of the American Public Health Association, Mexico City, Mexico, December 3, 4, 5, 6, 7, 1906. Columbus, Ohio, Fred. J. Heer, 1907.

SUMMARY OF ACCESSIONS.

From September 11th to October 7th, 1907.

Donations (including 7 duplicates)	101
By purchase	4
Total	105

MEMBERSHIP.

ADDITIONS.

(September 10th to October 8th, 1907.)

MEMBERS.

		Date of Membership.
BAKENHUS, REUBEN EDWIN. Naval Training Station, Newport, R. I.		Oct. 2, 1907
BROWN, WILLIAM LOWE. Res. Engr., Penn., N. Y. & L. I. R. R., 564 West 33d St., New York City	Assoc. M. M.	Sept. 6, 1905 Oct. 1, 1907
CARMALT, LAURANCE JOHNSON. Prin. Asst. Engr., Atlantic Ave. Impvt., Long Island R. R., Flatbush Ave. Terminal, Brooklyn, N. Y.		May 1, 1907
DOUGLAS, WALTER JULES. District Bldg., Washington, D. C.		April 3, 1907
HEWETT, BERTRAM HENRY MAJENDIE. Gen. Res. Engr., River Tunnels Section, North River Div., P. R. R. Tunnels, 564 West 33d St., New York City	Assoc. M. M.	April 5, 1905 Oct. 1, 1907
KENT, WILLARD. Narragansett Pier, R. I.		Oct. 2, 1907
McCULLOCH, ROBERT AUSTEN. Chf. Engr. with R. F. Almirall, 51 Chambers St., New York City	Jun. Assoc. M. M.	Sept. 2, 1902 Sept. 7, 1904 Sept. 3, 1907
MOWLDS, EUGENE. Care, Am. Bridge Co., Edge Moor, Del.		Oct. 2, 1907
POTTER, HERBERT LEROY. 511 Eighth St., Brooklyn, N. Y.		Oct. 2, 1907
ROBERTS, WILLIAM JACKSON. Assoc. Prof., Math. and Civ. Eng., State Coll. of Washington, Pullman, Wash.	Assoc. M. M.	June 6, 1900 Sept. 3, 1907
TEMPLE, EDWARD BRINTON. Asst. Chf. Engr., P. R. R. Co., Broad St. Station, Philadelphia, Pa.		Oct. 2, 1907

ASSOCIATE MEMBERS.

ADDISON, CHARLES LAMBERT. Asst. to Pres., Long Island R. R. Co., Long Island City, N. Y.		May 1, 1907
ALDERSON, ALGERNON BROWN. West Hartford, Conn.		Oct. 2, 1907
BAKER, PERCIVAL STEVENS. Computer, P. & R. Ry., 65th Ave. and Camac St., Oak Lane, Philadelphia, Pa.	Jun. Assoc. M.	Sept. 4, 1906 Oct. 2, 1907
BANKS, GEORGE HILL. U. S. Engr. Office, Houghton, Mich.		Sept. 4, 1907
BERGENDAHL, GUSTAVE STORM. 1430 Syndicate Trust Bldg., St. Louis, Mo.		April 3, 1907
BERGER, JOHN. 335 Madison Ave., Room 1136, New York City		Oct. 2, 1907
CARVER, GEORGE PAYSON. 53 State St., Boston, Mass.		Oct. 2, 1907
DIEDEN, GOTTHARD VINCENT. Malmo, Sweden		Oct. 2, 1907
FUCIK, EDWARD JAMES. 813 So. Sawyer Ave., Chicago, Ill.		Oct. 2, 1907

ASSOCIATE MEMBERS (*Continued*).

		Date of Membership.
GANDOLFO, JOSEPH HARRINGTON. Asst. Constr. Engr. with John Van Vleck, 100 Broadway, New York City.....		Oct. 2, 1907
GUNDERSEN, AUGUST. 605 Whitney Bldg., Detroit, Mich...		Oct. 2, 1907
HARPS, HARRY MACY. With Herbert C. Keith, Cons. Engr., 116 Nassau St., New York City	Jun. Assoc. M.	Mar. 3, 1903 Oct. 2, 1907
HOPKINS, NEWTON FISHER. 900 Lewis Bldg., Pittsburg, Pa.		Oct. 2, 1907
HORNE, HAROLD WELLINGTON. Cornwall-on-Hudson, N. Y..		Oct. 2, 1907
LEONARD, CLIFFORD MILTON. 1429 Monadnock Blk., Chicago, Ill....		Oct. 2, 1907
MANSFIELD, ROYAL JOHN. Structural Engr., Atlantic, Gulf & Pacific Co., Manila, Philippine Islands....	Jun. Assoc. M.	Dec. 2, 1902 July 10, 1907
MEANS, THOMAS HERBERT. Fallon, Nev....		July 10, 1907
MEYERS, CLARENCE WILLIAM. Asst. Engr., Rapid Transit Subway Constr. Co., 314 Riverside Drive, New York City....	Jun. Assoc. M.	Sept. 1, 1903 Oct. 2, 1907
PRESTON, CHARLES HENRY, JR. 24 Wyman St., Waterbury, Conn....		Oct. 2, 1907
SEKIBA, SHIGEKI. Penn Bridge Co., Beaver Falls, Pa......		Oct. 2, 1907
SKINNER, FREDERICK GARDINER. 41 Willis Ave. West, Detroit, Mich....		Sept. 4, 1907
SOLOMON, GABRIEL ROBERTS. 1622 Candler Bldg., Atlanta, Ga....		Oct. 2, 1907
STEVENSON, WILLIAM LAWRIE. 586 Jamestown Ave., Roxborough, Philadelphia, Pa....		Oct. 2, 1907
WARD, CHARLES CLARENCE. P. O. Box 140, Wenatchee, Wash....		July 10, 1907
YATES, EUGENE ADAMS. Asst. Engr., Penn., N. Y. & L. I. R. R. Co., 345 East 33d St., New York City....	Jun. Assoc. M.	Oct. 3, 1905 Oct. 2, 1907

ASSOCIATE.

COLE, GEORGE NATHAN. 277 Broadway, New York City....	Oct. 2, 1907

JUNIORS.

CARTER, LESTER LEVI. Care, Union Constr. Co., Camp D, Vallecito, Cal....	Sept. 3, 1907
COLE, ALDEN BRIGHAM. 56 No. Main St., Carbondale, Pa...	Sept. 3, 1907
CORP, HENRY WILLIAM. 308 Orms St., Providence, R. I....	Oct. 1, 1907
CURTIS, CLINTON ALONZO. Ft. Edward, N. Y....	Oct. 1, 1907
GALVIN, JAMES AUGUSTINE. Barge Canal Office, Mechanicsville, N. Y....	Sept. 3, 1907
KELLEY, MATTHEW DETOBIN. Care, San Juan Light & Transit Co., San Juan, Porto Rico....	Sept. 3, 1907
LORD, HAROLD. Office of Light-House Engr., Honolulu, Hawaii....	Sept. 3, 1907

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PAGON, WILLIAM WATTERS. 937 St. Paul St., Baltimore, Md.	Sept. 3, 1907
RICH, WILDER MELOY. 318 Spruce St., E., Sault Ste. Marie, Mich.	Sept. 3, 1907
RINDSFOOS, CHARLES SIESEL. Lock Box 2, Massena, N. Y.	April 2, 1907
TROWBRIDGE, ALFRED LOCKWOOD. Care, J. H. Wise, 925 Franklin St., San Francisco, Cal.	Sept. 3, 1907
YEO, WILLIAM ALBERT. Care, Hudson Companies, 111 Broadway, New York City	Oct. 1, 1907

CHANGES OF ADDRESS.

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BISSELL, FRANK EDWARD. 2185 E. 93d St., Cleveland, Ohio.

BROWN, CHARLES OTTO. Cons. Engr., 624 Madison Ave., New York City.

BROWN, LOUIS LIVINGSTON. Gen. Supt., The Foundation Co., 115 Broadway, New York City.

COOMBS, STEPHEN ELBRIDGE. 335 Madison Ave., Room 1136, New York City.

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HILL, WALTER HOVEY. Tenabo, Nev.

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MEMBERS (*Continued*).

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MILLIS, JOHN. Lt.-Col. of Engrs., U. S. A., Care, Chf. of Engrs., War Dept., Washington, D. C.

MORSE, GEORGE FREDERICK. Asst. Engr., C. R. R. of N. J., Pier 10, North River, Foot of Cedar St., New York City.

OCKERSON, JOHN AUGUSTUS. (*Vice-President*). Cons. Engr.; Member, Mississippi River Comm., 1301 Liggett Bldg., St. Louis, Mo.

OLNEY, ALFRED CLARENCE. 1015 Central Ave., Birmingham, Ala.

O'SHAUGHNESSY, MICHAEL MAURICE. Civ. and Cons. Engr.; Chf. Engr., Southern California Mountain Water Co., San Diego (Res., Mill Valley, Marin Co.), Cal.

PARKER, MAURICE STILES. Cons. Engr., 309 Bartlett Bldg., Joplin, Mo.

RICE, GEORGE STAPLES. Chf. Engr., Public Service Comm. for the First Dist., 154 Nassau St., New York City.

ROBBINS, SAMUEL BOSTWICK. Project Engr., U. S. Reclamation Service, Fort Shaw, Mont.

SCOTT, ADDISON MOFFAT. Charleston, Kanawha Co., W. Va.

SEAVER, JOHN WRIGHT. Caxton Bldg., Cleveland, Ohio.

SLIFER, HIRAM JOSEPH. Colon, Panama.

SNELL, THOMAS CULLEN BRYANT. Room 601, Lyceum Bldg., Duluth, Minn.

STUBBS, LINTON WADDELL. 808 Broadway St., New Orleans, La.

TABOR, ERNEST FREDERICK. Engr., U. S. Reclamation Service, Garland, Wyo.

TAYS, EUGENE AUGUSTUS HOFFMAN. Room 27, Jacobson Bldg., Denver, Colo.

VAN HOESEN, EDMUND FRENCH. Chf. Engr., Tonopah & Goldfield R. R., Tonopah, Nev.

WILLIAMS, EDWARD GILBERT. Chf. Engr., Constr. Dept., The New York Continental Jewell Filtration Co., 215 North Capitol St., Washington, D. C.

WILSON, CHARLES BEATTY. Prin. Asst. Engr., Cumberland River Bridges, Room 48, Cole Bldg., Nashville, Tenn.

WOODBURY, CHARLES JEPTHA HILL. Secy., The National Assoc. of Cotton Manufacturers, 45 Milk St., Room 501, Boston (Res., 51 Baltimore St., Lynn), Mass.

ASSOCIATE MEMBERS.

ALDERMAN, CLARENCE EDSON. Constr. Engr., The Norcross Bros. Co., 327 State St., Springfield, Mass.

ARMSTRONG, ALEXANDER FLOYD. 280 Broadway, Room 259, New York City.

BALDWIN, HIRAM ELLSWORTH. 10532 Earle Ave., Cleveland, Ohio.

BANTEL, EDWARD CHRISTIAN HENRY. Adjunct Prof. of Civ. Eng., Univ. of Texas, 505 West 19th St., Austin, Tex.

BRANNE, JOHN SEVERIN. Cons. Engr., 1 Madison Ave., New York City.

BROOKS, JOHN PASCAL. Associate Prof. of Civ. Eng., Univ. of Illinois, 1105 California Ave., Urbana, Ill.

BRUSH, WILLIAM WHITLOCK. 194 Hancock St., Brooklyn, N. Y.

BURGESS, GEORGE HECKMAN. Engr. of Terminal Impvts., Erie R. R. Co., 11 Broadway, New York City (Res., 25 Fairfield St., Montclair, N. J.).

ASSOCIATE MEMBERS (*Continued*).

CARROLL, CHARLES JOSEPH. Apartado 336, Torreon, Coah., Mexico.

CREW, CHARLES CORWIN. Care, Wyckoff Wood Pipe Co., Elmira, N. Y.

DALLIS, PARK ANDREW. 1023 Candler Bldg., Atlanta, Ga.

DUIS, FREDERICK BERNHARDT. U. S. Engr. Office, Wheeling, W. Va.

ELROD, HENRY EXALL. Mgr., Houston Structural Steel Works, 2906 Caroline St., Houston, Tex.

EVERHAM, ARTHUR CASSIDY. Asst. Tunnel Engr., Detroit River Tunnel Co., M. C. Depot, Detroit, Mich.

FRENCH, FRANK CHAUNCEY. Associate Prof. of Civ. Eng., Univ. of Utah, Salt Lake City, Utah.

FRY, LESLIE MONROE. Tipton, Mo.

HAIN, JAMES C. 1284 Pacific St., Brooklyn, N. Y.

HAMMATT, WILLIAM CUSHING. Chf. Engr., Miller & Lux, Inc., 1316 Merchants Exchange Bldg., San Francisco, Cal.

HAWXHURST, ROBERT, JR. Gen. Mgr., Poderosa Min. Co., Care, Anglo-South Am. Bank, Antofagasta, Chili (also Cons. Engr., 10 Austin Friars, London, E. C., England).

HAYLOW, JAMES HENRY. Engr. in Chg. of Track and Roadway, Ford, Bacon & Davis, P. O. Box 341, Memphis, Tenn.

HEALD, EDWARD CRESWELL. Chf. Structural Engr., Office of Superv. Archt., Treasury Dept., 1717 Twentieth St., Washington, D. C.

HODGDON, JOHN BREWSTER. 2101 Wall St., Joplin, Mo.

HUESTIS, CHARLES CALVIN. Gen. Mgr., Essex Constr. Co., 279 Highland Ave., Buffalo, N. Y.

LOVE, ANDREW CAVITT. Res. Engr., Baton Rouge Branch, Morgan's Louisiana & Texas R. R. & Steamship Co., Grosse Fete, La.

MACHEN, HENRY BENNETT. Asst. Engr., Dept., Water Supply (Res., 315 West 97th St.), New York City.

MACY, ELBERT CLYDE. Supt. of Constr., Stone & Webster Eng. Corp., 623 Crocker Bldg., San Francisco, Cal.

MCDANIEL, ALLEN BOYER. Prof. of Civ. Eng., Univ. of South Dakota, Vermilion, S. Dak.

PATERSON, HARRY THOMAS. Care, U. S. Engr. Office, Wilmington, N. C.

POST, WILLIAM SCHUYLER. 108 Sutter St., Room 402, San Francisco, Cal.

PRESSEY, HENRY ALBERT. Hibbs Bldg., Washington, D. C.

PRITCHETT, CHARLES MARCELLUS. Dungannon, Va.

SAUNDERS, GEORGE CROSBY. 80 Wall St. (Res., 559 West 183d St.), New York City.

SCHREIBER, JOHN MARTIN. Engr., M. of W., Public Service Corp. of New Jersey, Street Railway Dept., Passaic Wharf, Newark, N. J.

SCHWARZE, CARL THEODORE. 404 Sixth St., Brooklyn, N. Y.

SEARLE, CHARLES DEPEW. Asst. Engr., Rapid Transit Comm., 32 West 126th St., New York City.

SEVERSON, OSCAR MELVERN. 26 Sheridan St., Auburn, N. Y.

SMITH, COURTLAND ELMORE. Asst. Engr. in Charge, Main Dam, Croton Falls Reservoir, P. O. Box 156, Brewster, N. Y.

ASSOCIATE MEMBERS (*Continued*).

STEARNS, FRED LINCOLN. Scarsdale, N. Y.

TURNER, GEORGE DALLAS BAIRD. 94 Carnegie Ave., East Orange, N. J.

VERVEER, EMANUEL LOUIS. 161 West 103d St., New York City.

WALLACE, WILLIAM McGEHEE. 2028 F St., N. W., Washington, D. C.

WATSON, IRVINE. Supt. of Constr., U. S. Reclamation Service, 114 South 6th St., North Yakima, Wash.

WELLER, FRANCIS REPETTI. (Pressey & Weller, Civ. and Hydr. Engrs.), Hibbs Bldg., Washington, D. C.

WELLS, GEORGE MILLER. Care, Isthmian Canal Comm., Gatun, Canal Zone, Panama.

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JUNIORS.

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JUNIORS (*Continued*).

HUMPHREY, FREDERIC LEAROYD. Care, U. S. Reclamation Service, Klamath Falls, Ore.

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MAUPIN, EDGAR STAPLES. Box 404, U. S. Engr. Office, Vicksburg, Miss.

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RACKLE, OSCAR WILLIAM. Head Draftsman, Rhode Island State Board of Public Roads; Asst. Instr. of Civ. Eng., Brown Univ., 94 Angell St., Providence, R. I.

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WILBANKS, JOHN ROBERT. 203 North 10th St., Mt. Vernon, Ill.

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WRIGHT, GEORGE CREIGHTON. 51 Webster Ave., Rochester, N. Y.

FELLOWS.

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DEATHS.

PLYMPTON, GEORGE WASHINGTON. Elected Member January 29th, 1868; died September 11th, 1907.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(September 11th to October 7th, 1907.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Blk., Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 803 Fulton Bldg., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Electric Railway Review*, Chicago, Ill., 10c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal, London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.
(86) *Engineering and Contracting*, Chicago, Ill.
(87) *Roadmaster and Foreman*, Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels.

LIST OF ARTICLES.

Bridge.

The Distribution of Stress in Rivetted Connections.* C. R. Young, S. Can. Soc. C. E. (5) Vol. 20, Pt. 2.
The Durability of Wire Rope under Severe Conditions.* T. H. Schwitzer, Stud. Can. Soc. C. E. (5) Vol. 20, Pt. 1.
The Quebec Bridge Disaster.* (11) Sept. 6; (13) Sept. 12; (12) Sept. 6.
The Quebec Bridge.* Frank W. Skinner, M. Am. Soc. C. E. (11) Sept. 13.
The Erection of the Las Vacas Viaduct.* (14) Sept. 14.
The Substructure of the Dearborn Street Bridge, Chicago.* (14) Sept. 14.
The Collapse of the Quebec Bridge. Frank W. Skinner, M. Am. Soc. C. E. (11) Sept. 20.
The Suspended Falsework of the Cantilever Arms of the Quebec Bridge.* (14) Sept. 21.
Specifications for Creosoting Oregon Fir Piling and Bridge Timber, A. T. & S. F. Ry. (18) Sept. 21.
The New Steel Viaduct between Kansas City, Mo., and Kansas City, Kan.* (13) Sept. 26.
Reinforced Concrete Viaduct, Richmond and Chesapeake Bay Railway.* (40) Sept. 27.
Continuous Girders.* (12) Sept. 27.
Calf Killer Bridge, Nashville, Chattanooga & St. Louis Ry.* (14) Sept. 28.
The Kafue River Bridge on the Cape to Cairo Railroad.* (19) Sept. 28.
The Erection of the South Cantilever Arm of the Quebec Bridge.* (14) Sept. 28.
The Melwood Avenue Retaining Wall, Pittsburg.* (14) Sept. 28.
Imperfect Butt-Joints in Columns and Stresses in Lattice-Bars.* Henry S. Prichard, M. Am. Soc. C. E. (13) Oct. 3.
La Catastrophe des Ponts-de-Cé (Maine-et-Loire).* Jean Phizen. (33) Sept. 14.
Strassenbrücke in Eisenbeton über die Rixdorf-Mittenwalder Kleinbahn.* Wüg. (51) Aug. 28.
Ermittlung der Drucklinie Elastisch Eingespannter Gewölbe. Em. Haimovici. (78) Sept.
Brückenbauprojekt Rieden-Sauterach über die Bregenzer Ach.* M. Heimbach. (78) Sept.

Electrical.

Polyphase Systems of Generation, Transmission and Distribution.* M. A. Sammett A. M. Can. Soc. C. E. (5) Vol. 20, Pt. 2.
The Application of the Storage Battery to Lighting, Power and Railway Service.* J. M. S. Waring. (4) Aug.
Fractional Pitch Windings for Induction Motors.* C. A. Adams, W. K. Cabot, and G. Æ. Irving, Jr. (42) Aug.

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Electrical—(Continued).

Electrical Developments in Rio de Janeiro.* (26) Sept. 6.
A Method of Determining the Leading Dimensions of Large and High-Speed Continuous Current Dynamos.* H. M. Hobart. (26) Serial beginning Sept. 6.
Electric Cranes. H. H. Broughton. (73) Serial beginning Sept. 6.
Mechanical Action of Currents on Conductors.* P. Bary. (Tr. from *L'Eclairage Electrique*.) (73) Sept. 6.
Mercurous Sulphate, Cadmium Sulphate and the Cadmium Cell.* G. A. Hulett. (From the *Physical Review*.) (73) Sept. 6.
Insurance and Inspection of Electrical Machinery.* (47) Sept. 7.
Recent Advances in Artificial Lighting.* (13) Sept. 12.
Forces in the Interior of an Electric Conductor.* Edwin F. Northrup. (Abstract of paper read before the Amer. Physical Soc.) (73) Sept. 13.
The Design of Transformers as Influenced by the Employment of Alloy-Sheets.* Robert Pohl. (Abstracted from the *Elektrotechnische Zeitschrift*.) (73) Sept. 13.
Abnormal Primary Current and Second Voltage on Placing a Transformer in Circuit.* Trygve Jensen. (27) Sept. 14.
Switchboard Connections of Wattmeters and Watt-Hour Meters for Measuring Power and Energy in Polyphase Circuits.* Paul MacGahan. (27) Sept. 14.
The Poulsen Arc as a Means of Obtaining Continuous Electrical Oscillations.* J. A. Fleming. (Abstract of a paper read before the Physical Soc.) (73) Sept. 20.
The Electric Elevator Equipment for a Tall Office Building.* (14) Sept. 21.
The Design of Plunger Magnets.* C. P. Nachod. (27) Sept. 21.
On the Elementary Theory of Electric Oscillators.* J. A. Fleming. (73) Sept. 27.
Resistance Coils and Comparisons.* C. V. Drysdale. (Paper read before the Brit. Assoc.) (73) Sept. 27.
Wireless Telephony for the United States Navy.* Herbert T. Wade. (46) Sept. 28.
Elements of Electrical Engineering.* A. E. Watson. (19) Serial beginning Sept. 28.
The Tofwehult-Westerwik Transmission System, Sweden.* Arvid Westerberg. (27) Sept. 28.
Magnetic Hysteresis Phenomena.* M. O. Bloser. (27) Sept. 28.
Tension and Sag in Wire Spans.* Harold Pender. (27) Sept. 28.
Electro-Magnets for Lifting and Handling Materials.* Charles R. Benjamin. (10) Oct.
The Hydro-Electric Plant of the West Kootenay Power & Light Co., Ltd.* (14) Oct. 5.
The New Power Plant of the Lowell Electric Light Corporation.* (27) Oct. 5.
System at Minneapolis for Distributing the Energy Transmitted from Taylor's Falls.* (27) Oct. 5.
Wiring and Connections for Constant Potential Transformers.* Geo. A. Burnham. (27) Oct. 5.
Neuerungen an Indikatoren.* A. Wagener. (48) Aug. 31.
Das Heylandsche Verfahren zum Anlassen und Regulieren und zur Kompensation der Phasenverschiebung von Induktionsmotoren.* Friedrich G. Wellner. (Paper read before the Dresdener Elektrotechnische Verein.) (48) Sept. 7.

Marine.

The Electrical Plant and Means of Interior Communication of a Modern Ocean-Going Passenger and Cargo Vessel.* Chas. J. Dougherty. (2) July.
Explosive-Mixture Motors.* Commander A. B. Willits. (Abstract from the *Journal* of the Amer. Soc. of Naval Engrs.) (12) Serial beginning Sept. 13.
Design and Arrangement of Marine Turbines and Propellers. Ernest N. Janson. (Paper read before the Amer. Soc. of Naval Engrs.) (47) Sept. 14.
The Electrical Equipment of the SS. *Mauretania*. (73) Serial beginning Sept. 27.
Superheating in Marine Practice.* (47) Serial beginning Sept. 28.
Le Paquebot à Turbines *Lusitania* de la Compagnie Cunard.* L. Piaud. (33) Serial beginning Sept. 21.

Mechanical.

Heating and Ventilation of St. Paul's Hospital, Montreal, Que.* Allan G. McAvity, S. Can. Soc. C. E. (5) Vol. 20, Pt. 1.
The Development of Electricity in the Iron and Steel Industries.* D. Selby Bigge. (71) Vol. 73.
An Investigation on the Use of Steam in Gas-Producer Practice.* William Arthur Bone and Richard Vernon Wheeler. (71) Vol. 73.
Sentinel Pyrometers and their Application to the Annealing, Hardening, and General Heat Treatment of Tool Steel.* Harry Brearley and F. Colin Moorwood. (71) Vol. 73.
Induced Draught, with Hot Air Economisers for Steel-Works and Blast-Furnace Boilers.* A. J. Capron. (71) Vol. 73.
Notes on the Use of Producer Gas for Power Purposes.* J. R. Bibbins. (2) July.
Western Ways in American Gas Business.* Archibald S. B. Little. (66) Sept. 3.
Presidential Address (Burslem Gas-Works). (Read before the Wales and Monmouthshire District Inst. of Gas Engrs. and Mgrs.) (66) Sept. 10

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Mechanical—(Continued).

A Stripping Excavator with a Conveyor to Form the Waste Bank.* (13) Sept. 12.
The Canada Tool Works; the Enlarged Plant of the John Bertram & Sons Company at Dundas, Ontario.* H. R. Cobleigh. (20) Sept. 12.
A Bar Iron and Light Rail Mill; the Loucks Iron & Steel Company's Plant, Roanoke, Va.* (20) Sept. 12.
1 000-Kilowatt British Thomson-Houston Turbo-Alternator Set.* (11) Sept. 13; (26) Sept. 13; (73) Sept. 13; (22) Sept. 13.
The Capacity of Cooling Towers.* C. O. Schmitt. (Abstract of paper read before the South African Assoc. of Engrs.) (12) Sept. 13.
The Aeroplane Experiments of M. Louis Bleriot.* Ferber. (19) Sept. 14.
The Power Plant of the Elgin National Watch Works.* (14) Sept. 14.
Trials of a 500 B. H. P. Diesel Oil Engine.* (From Annual Rept. of Chief Engr. of the Brit. Engine Boiler and Elec. Insurance Co.) (47) Sept. 14.
An English Boiler Improvement; the Temperley-Cockburn System.* (20) Sept. 19.
Strength Test of a Contractor's Dumping Wagon.* (13) Sept. 19.
The Forges and Mines of the Hungarian State.* (12) Sept. 20.
The Cooling Plant for Walter Baker & Co., Ltd., Dorchester, Mass.* (14) Sept. 21.
A New Method of Condensing and Scrubbing.* Wm. Seymour. (Paper read before the Mich. Gas Assoc.) (24) Sept. 23.
Investigations on the Long-Distance Gas-Main at St. Gall, Switzerland.* A. Fliegner. (Abstracts from the *Journal für Gasbeleuchtung* and the *Schweizerische Bauzeitung*.) (66) Sept. 24.
The Bethlehem Steel Company's New Plant.* (20) Sept. 26.
Alcohol for Operating Engines. Charles E. Lucke. (Abstract of a report to the Dept. of Agri.) (20) Sept. 26.
The Engineering and Machinery Exhibition, Olympia.* Joseph Horner. (11) Serial beginning Sept. 27.
Pressure Gauges. Strohmeyer. (From *Memorandum* of Manchester Steam Users Assoc.) (12) Serial beginning Sept. 27.
A Recent High Pressure Installation.* E. C. Jones, M. Am. Soc. M. E. (Paper read before the Pacific Coast Gas Assoc.) (24) Sept. 30.
How to Set the Valves of a Duplex Pump.* F. F. Nickel. (64) Oct.
Technical Aspects of Oil as Fuel.* Franz Erich Junge. (64) Serial beginning Oct.
Flue-Gas Analysis: Its Value. Joseph W. Hays. (64) Oct.
Steam-Engine Foundation.* R. T. Strohm. (64) Oct.
Modern Safety Devices for Prime Movers.* C. C. Major. (64) Oct.
Compounding Piston Engines with Turbines.* A. Rateau. (64) Oct.
The Speed Regulation of Steam Engines.* Sterling H. Bunnell. (10) Oct.
Why Do Some Coals Coke? F. C. Keighley. (Paper read before the Coal Min. Inst. of Amer.) (45) Oct.
Municipal Cement Plant for the Los Angeles Aqueduct. (Specifications.) (13) Oct. 3.
Studies in the Manufacture of Coal Gas.* Alfred H. White and Fred E. Park. (Paper read before the Mich. Gas Assoc.) (24) Oct. 7.
Le Diagramme Entropique appliqué à l'Etude des Cycles Effectués par l'Intermédiaire des Gaz Permanents.* H. Mottet. (31) Vol. 6, Pt. 1.
Ponton-Bigue de 60 Tonnes, à Portée Variable Employé au Canal de Suez.* Ch. Dantin. (33) Aug. 31.
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Die Umlaufzahlenreihen bei Werkzeugmaschinen. Franz Adler. (48) Sept. 21.
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The Ageing of Mild Steel.* C. E. Stromeyer. (71) Vol. 73.
Manufacture of Steel from High-Silicon Phosphoric Pig Iron by the Basic Bessemer Process. Arthur Windsor Richards. (71) Vol. 73.
A Method of Producing High-Class Steel from Pig Iron containing Chromium, Nickel and Cobalt. Arthur Windsor Richards. (71) Vol. 73.
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Notes on Antimony Smelting.* G. Pautrat. (16) Sept. 14.
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Special Ferro-Alloys for the Foundry.* E. Houghton. (Paper read before the Brit. Foundrymen's Assoc.) (22) Sept. 20.
Lead and Copper Smelting at Salt Lake.* Walter Renton Ingalls. (16) Serial beginning Sept. 21.

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Notes on Waihi Ore Treatment.* Ralph Stokes. (Paper read before the Chem., Metal. and Min. Soc. of South Africa.) (68) Sept. 28.
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Milling Practice at the Granadena Mill.* S. F. Shaw. (16) Oct. 5.
Ueber die Chrombestimmung im Stahl, insbesondere bei Anwesenheit von Wolfram. G. v. Knorre. (50) Aug. 28.
Die Erzeugung von Roheisen im Elektrischen Ofen.* B. Neumann. (50) Aug. 28.
Ueber Bleibende Spannungen in Werkstücken infolge Abkühlung. E. Heyn. (50) Serial beginning Sept. 11.

Military.

Les Explosifs Modernes.* H. Schmerber. (33) Serial beginning Aug. 31.

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The Sinking of Bentley Colliery.* J. W. Fryar and Robert Clive. (Paper read before the Inst. of Min. Engrs.) (22) Sept. 6; (57) Sept. 6.
Roof Weights in Mines.* H. T. Foster. (Paper read before the Inst. of Min. Engrs.) (22) Sept. 6; (57) Sept. 6.
Deep Boring at Barlow near Selby. H. St. John Durnford. (22) Sept. 6; (57) Sept. 6.
Gold Mining and Gold Production.* John Walter Gregory. (29) Serial beginning Sept. 13.
A New Method of Shaft Connection.* Henry Briggs. (16) Sept. 14.
Explosives in Coal Mines.* E. J. Deason. (22) Sept. 20.
Nickel Mining in New Caledonia.* G. M. Colvocoresses. (16) Sept. 28.
Improvements in the Vertical-Plunger Sinking Pump.* A. H. Hale. (16) Sept. 28.
A Modern Illinois Coal Plant.* (45) Oct.
Coal-Dust Explosions in Collieries.* James Ashworth. (10) Oct.
Construction of Tracks in Coal Mines.* M. S. Hachita. (16) Oct. 5.
Les Explosifs Modernes.* H. Schmerber. (33) Serial beginning Aug. 31.

Miscellaneous.

Optical Pyrometry. L. Holborn. (Paper read before the Brit. Assoc.) (11) Sept. 6.

Municipal.

Suggestions for Opening Streets through Girard College Grounds.* Henry Leffmann. (2) July.
Cost of a Macadam Road in Maryland. (86) Sept. 25.

Railroad.

Notes on the Shops and Power House of the Canada Car Company.* E. G. M. Cape, A. M. Can. Soc. C. E. (5) Vol. 20, Pt. 1.
Dynamometer Car Experiments on the Boston and Maine Railroad.* H. O. Keay. (5) Vol. 20, Pt. 2.
Track-Circuit Signaling on Electrified Roads.* L. Frederic Howard. (42) Aug.
Commutating-Pole Direct-Current Railway Motors.* E. H. Anderson. (42) Aug.
Regeneration of Power with Single-Phase Electric Railway Motors.* William Cooper. (42) Aug.
Automotors and Light Trains on the English Railways.* Frahm. (From *Zeitung des Vereins*.) (88) Sept.
Experiments with Reinforced Concrete Ties in America.* W. M. Camp. (From *Journal and Report of Proceedings* of the Permanent-Way Institution.) (88) Sept.
The Completion of the Electric Signalling System at Brussels Nord Station.* (From *Chronique des Travaux Publics*.) (88) Sept.
Florida East Coast Railway Extension.* Howard Egleston. (87) Serial beginning Sept.
Report of Committee on Best Methods of Maintaining the Track for the Tonnage and Speed of To-day. (From the *Proceedings* of the Roadmasters' and M. of W. Assoc.) (87) Sept.
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A Method of Laying Vitrified Conduits for Electrical Cables and a Collapsible Core for Forming Conduits in Concrete without the Use of Vitrified Ducts (Bergen Hill Tunnels, P. R. R.).* F. Lavis, M. Am. Soc. C. E. (13) Oct. 3.
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Comparative Résumé of the Sewage Purification Tests at Columbus, Ohio. George W. Fuller. (Paper read before the Boston Soc. of Civ. Engrs.) (1) Aug.
Testing of Clay and Concrete Pipes. Buchartz and Stock. (Abstract of reports of the royal building material testing dept. at Gross-Lichterfelde.) (60) Oct.
Engineering Studies of a Typhoid Outbreak at the State Hospital, Trenton, N. J. Earle B. Phelps. (Abstract of a report to the N. J. State Sewerage Comm.) (13) Oct. 3.
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Formulas for Reinforced Concrete Beams. Henry Goldmark, M. Can. Soc. C. E. (5) Vol. 20, Pt. 1.
The Durability of Wire Rope under Severe Conditions.* T. H. Schwitzer, Stud. Can. Soc. C. E. (5) Vol. 20, Pt. 1.
Observations on some Physical Characteristics of Cast-Iron.* James Christie. (2) July.

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How to Prevent a Failure in Concrete Construction. W. Michaelis, Jr. (4) Aug.
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Stresses in Lattice Bars of Built Columns.* Thomas H. Johnson, M. Am. Soc. C. E. (13) Sept. 26.
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Qualities and Methods of Using Cement. S. B. Newberry. (Abstract of a paper read before the Ohio Builders' Supply Assoc.) (60) Oct.
The Steaming of Timber. Octave Chanute. (Abstract of paper read before the National Assoc. of Wood Preservers.) (60) Oct.
Method and Cost of Constructing Reinforced Concrete Kiln House of Separately Molded Members, Edison Portland Cement Co.* (86) Oct. 2.
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Wohn- und Geschäftshaus Wien VII, Mariahilferstrasse 58.* Felix Adutt. (78) Sept.
Beitrag zur Berechnung Steifer Rahmenkonstruktionen. Otto Leuprecht. (78) Serial beginning Sept.
Ein Weg zur Analytischen und Graphischen Behandlung des mit Eisen Armierten Betonquerschnittes, bei Möglichster Anpassung an die Wirklichen Spannungs-Dehnungskurven des Betons.* Rudolf Pokorny. (53) Sept. 6.
Die Gründung mit "Simplex"-Betonpfählen.* W. Siegfried. (51) Serial beginning Sept. 11.
Prüfverfahren für Gehärteten Stahl unter Berücksichtigung der Kugelform. R. Stribeck. (48) Sept. 14.
Das Hamburgische Seehospital (Nordheim-Stiftung) in Sahlenburg bei Cuxhaven.* Hugo Groothoff. (51) Sept. 18.
Kritische Betrachtungen über die im Deutschen Reich geltenden Vorschriften über die Berechnung der Standfestigkeit von Schornsteinen.* Raab. (Paper read before the Verein deutscher Firmen für Schornsteinbau und Feuerungsanlagen.* (80) Sept. 24.

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Toronto's Experience with Conduits. C. L. Fellowes. (5) Vol. 20, Pt. 1.
A Colorado Mountain Reservoir.* R. M. Hosea. (4) Aug.
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Masonry Dams.* Thomas G. Bocking. (12) Sept. 27.
Experiments with Submerged Tubes 4 Feet Square.* C. B. Stewart. (14) Sept. 28.
Examination of Water Purification Plant at Owensboro, Ky.* Philip Burgess, Assoc. M. Am. Soc. C. E. (14) Sept. 28.
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A Collapsible Steel Dam Crest, Bear River, near Garland, Utah.* J. C. Wheelon. (13) Oct. 3.
Waste-Water Investigations in Philadelphia.* (14) Oct. 5.

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Tide Levels and Datum Planes on the Pacific Coast of Canada. W. Bell Dawson, M. Inst. C. E., M. Can. Soc. C. E. (5) Vol. 20, Pt. 1.
Mechanical Canal Locks in Canada.* Walter J. Francis, M. Can. Soc. C. E. (5) Vol 20, Pt. 1.

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THE REINFORCED CONCRETE WORK OF THE McGRAW BUILDING.

By William H. Burr, M. Am. Soc. C. E.

To be Presented November 20th, 1907.

The McGraw Building is a true reinforced concrete structure—the latest type of buildings of that general class. It is on the north side of West Thirty-ninth Street, between Seventh and Eighth Avenues, in the City of New York, in that district which has already felt the stimulating influence of the new Pennsylvania Railroad Station in process of construction a half dozen blocks to the south. This part of the city is undoubtedly destined to become a great business center, where substantial buildings of the highest type will be required in order to meet the demands of the development of that vicinity.

The building has a frontage of 126.3 ft. on Thirty-ninth Street, and a depth of 90 ft. It has eleven stories, and a penthouse, or roof structure, nearly equivalent to another floor. The height of the roof is 145 ft. above the ground floor, or nearly 150 ft. above the street, or, finally, 159 ft. 6 in. above the basement floor. While, therefore, it is far from ranking among the tallest sky-scrapers of the city, it is to be classed among the high business buildings of Manhattan Island. Its

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

THE McGRAW BUILDING

height is much greater than has heretofore been considered practicable for a purely reinforced concrete building, *i. e.*, a concrete building without iron or steel columns.

It has been constructed for the McGraw Realty Company primarily to accommodate the business of the McGraw Publishing Company, whose publications include *The Engineering Record, Electrical World, Street Railway Journal* and the *Electro-Chemical* and *Metallurgical Industries*. At the same time, it was designed to accommodate not only the printing presses of the McGraw Publishing Company, but any other similar business requiring the operation of heavy machinery or the storage of heavy goods in bulk. It was imperatively necessary, therefore, that the building should be designed and built so as to afford the greatest possible resistance to the vibration of heavy machinery, and possess to an unusual degree both rigidity and durability. It is also fire-proof to such an extent that the McGraw Realty Company may reasonably be its own insurer. While the building is admirably adapted to office use, its lower floors, particularly, are thus capable of affording provision for those business purposes which require heavy and substantial construction.

Like most other portions of that part of the city north of Fourteenth Street, the rock originally at the site of the building was close to the surface. The excavations for the foundation were not carried deeper than about 20 ft. below the street surface, and there the entire foundation was placed upon the gneiss which forms the ledge or bedrock. There were no real foundation problems to be solved. The columns supporting the building, and the retaining or area walls around the basement, were all founded upon the same ledge, under the requirements of the Building Code of the City of New York.

In order to meet the exacting requirements for the unusually substantial structure required by the McGraw Publishing Company, it was decided to design the building for a live load of 250 lb. per sq. ft. for the first and second floors, 200 lb. per sq. ft. for the third floor, 150 lb. per sq. ft. for the fourth floor and 125 lb. per sq. ft. for all the other floors above the fourth, and with a live load of 60 lb. per sq. ft. for the roof. All parts of the floor beams and girders, therefore, and the columns, were designed to sustain, under the requirements of the Building Code, the actual weight of the structure and the live load specified above.

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an adjoining building. The concrete within the exterior dimensions or outline of the steel angles is available for carrying a compressive or column load. As it is completely embraced or surrounded by the steel angles and lacing bars, it is steel "banded" in the most effective manner possible. Its enclosure in the steelwork of the column is so rigid, manifestly, that lateral strains under column loads must be greatly reduced—in fact, nearly prevented—within any ordinary limits of loading. Such concrete, therefore, is largely prevented from the usual yielding of that material under compression, and its compressive carrying capacity is increased. This is not only obvious from the condition of the concrete in these columns, but that view is confirmed by the comparatively few results of tests of concrete columns of this character. When, therefore, the plans of these columns were submitted to the Bureau of Buildings of the City of New York for examination and final approval, a special regulation was made permitting the concrete to carry a maximum working load of 750 lb. per sq. in. within the exterior limits of the steel angles, the exterior 2 in. of concrete, as stated previously, being considered simply a fire-protecting shield. This increased permissible load upon the concrete is coupled with the further provision that the cross-section of the steel in any column at any floor shall be sufficient to carry the entire dead load above that section without stressing the steel to more than 16 000 lb. per sq. in.

The use of the steel, in load-supporting condition, as a long column independent of the concrete, and at the same time forming a rigid banding member for the latter, with the consequent increase of permissible working load on the concrete, reduced the size of the columns in the basement and lower stories to dimensions quite consistent with the desired convenient and economical use of the clear floor space. Columns of this general type combine with their high carrying capacity great convenience in erection, for their steel sections may be erected ahead of the concrete work and afford convenient supporting members for the adjoining forms or for other erection work. The lacing bars, rivet heads, and other projecting column details act positively in creating a firm and complete hold or bond between the steelwork of each column and the concrete enclosed within it. This feature of these columns compels the steel and the enclosed concrete to act as a unit, and this action is enhanced by placing all the lacing

bars in one direction inside the steel angles, the other set being placed outside, as shown on the plans.

The Building Code requires the ratio between the moduli of elasticity for the steel and concrete to be taken as 12. Hence, as the permissible compressive working stress in the concrete was taken at 750 lb. per sq. in., the corresponding working stress in the steel would be 9 000 lb. per sq. in.

The largest columns (in the basement) have exterior dimensions of 29 by 29 in., but, at the eleventh story, the exterior dimensions are reduced to 14 by 14 in. These columns were built in sections of a length equal to the combined height of two stories, *i. e.*, 25 ft. The extra metal involved in this procedure was too small to be of practical consequence, and the expense of half the joints, if a change of section had been made at every floor, was saved. Much time was also gained in the erection of the steelwork. The abutting ends of the column sections were faced, and the joints were made by suitable splice-plates. Where there was a change in the exterior dimensions of the steelwork, full-strength splices were made by riveting suitable short-angle sections on the interior of the splice-plates of the lower part of the joint. These details are also shown on the plans.

The ratio of the area of steel section to that of the concrete for the various columns varied from 10% in the basement, where the steel carries about 57% of the total load, to 3½% in the ninth floor, where 30% of the total load is carried by the steel. The requirements of the Building Code for a design of this type raises the percentage of steel to much higher values than in ordinary concrete-steel work.

Table 1 shows the number and sizes of steel angles used throughout the main columns of the building.

The design of the floors, in general, is quite similar to that usually found in buildings of this class, although there are certain important details which do not come under that observation. As the plans indicate, the spacing of the columns is such as generally to divide each floor into panels 21 ft. 9 in. by 14 ft. 8 in. between centers of columns, the clear span of the main girders between columns being 14 ft. 8 in. less the width or diameter of the column section. The clear span of the floor beams between the main girders is 21 ft. 9 in. less the width of these girders. These prevailing lengths of spans of the beams and girders were modified at a few points in each floor to accommodate

Holes

Holes

Holes

Holes

TABLE 1.—NUMBER AND SIZES OF STEEL ANGLES USED IN THE MAIN COLUMNS OF THE McGRAW BUILDING.

Floor	Sizes of Steel Angles in Columns, and outside dimensions of Steel Columns, *i. e.*, back to back of Angles.			
11....	4 L's, 3½ by 3½ by $\frac{5}{16}$ in. 10 by 10 in., b. to b.	4 L's, 3½ by 3½ by $\frac{5}{16}$ in. 10 by 10 in., b. to b.	[illegible]	[illegible]
10....	4 L's, 8 by 8 by $\frac{7}{16}$ in. 17 by 17 in., b. to b.	4 L's, 3½ by 3½ by $\frac{5}{16}$ in. 10 by 10 in., b. to b.		
9....	4 L's, 8 by 3 by $\frac{7}{16}$ in. 17 by 17 in., b. to b	4 L's, 3½ by 3 by ⅜ in. 17 by 17 in., b. to b.		
8....	4 L's, 5 by 8 by $\frac{11}{16}$ in. 18¼ by 18¼ in., b. to b.	" " " " " "		
7....	" " " " " "	4 L's, 6 by 4 by ¾ in. 18¼ by 18¼ in., b. to b.		
6....	4 L's, 6 by 4 by $\frac{13}{16}$ in. 20¼ by 20¼ in., b. to b.	" " " " " "		
5....	" " " " " "	4 L's, 6 by 6 by $\frac{13}{16}$ in. 20¼ by 20¼ in. b. to b.		
4....	4 L's, 8 by 6 by ⅞ in. 22 by 22 in., b. to b.	" " " " " "		
3....	" " " " " "	4 L's, 8 by 6 by ⅞ in. 22 by 22 in., b. to b.		
2....	4 L's, 8 by 6 by 1 in. 24 by 24 in., b. to b.	" " " " " "		
1....	" " " " " "	4 L's, 8 by 6 by 1 in. 25 by 25 in., b. to b.		
Basement....	4 L's, 8 by 6 by 1 in. 25 by 25 in., b. to b.	" " " " " "		

such features of construction or details of floor space as stairways, elevator shafts, and similar details.

As the plans indicate, all floor-girder and beam reinforcement was of round steel rods, of sizes running generally from $\frac{3}{4}$ in. to $1\frac{3}{8}$ in. in diameter. These rods were grouped in one plane on the tension side of each beam or girder. As a rule, every alternate rod was bent upward at the end of each span so as to rise within about 2 in. of the top of the concrete, from which point it continues through either the main girder or the adjoining column, as the case may be, into the adjoining span well toward the quarter point of the latter. By these means, true continuity of beams and girders was secured in every case. In addition to this, the end of each rod was bent down, forming a right-angled turn, with an arm from 2 to 3 in. long, thus insuring a rigid bond or connection with the concrete. This main detail, formed by carrying the rods through the girders and columns, is an important feature in securing continuity and rigidity in the general construction of the building. It is believed to be one of the most important details of the best design of reinforced concrete building construction, and it should be secured either in the manner adopted in this building or by some other procedure of at least equal excellence.

The proper spacing of these reinforcing rods was secured by suitable supporting details throughout the length of the beams and girders themselves and by notches cut in angle-brackets riveted on the columns where they joined the latter members. At the columns, rigidity of connection was secured by bolting clamps through the angle-brackets just named and jamming the rods by tightening the nuts against those brackets. This secured an exceedingly strong metal connection between the reinforcing rods and the steel columns, aside from the further rigidity produced by the concrete mass of the intersecting columns, beams, and girders. These details, shown on the plans, were designed with care for the purpose of securing the strongest possible steel connections between the beams or girders and the columns, it being one of the main purposes to attain rigid continuity between floors and columns, and floors and outside walls. It is believed that unusual stiffness and strength have been given to this building by these means.

All beam and girder computations required by the floor designs were made in accordance with the provisions of the Building Code of the City of New York, the usual common theory of flexure formulas

PLATE XCIII.
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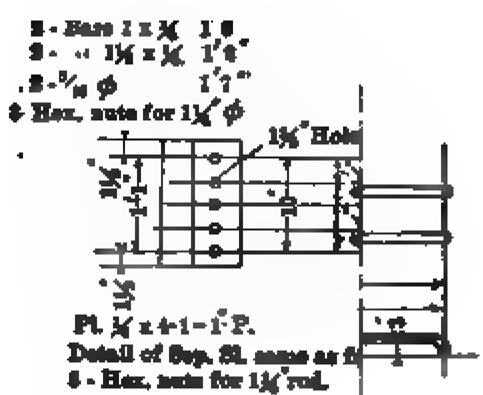
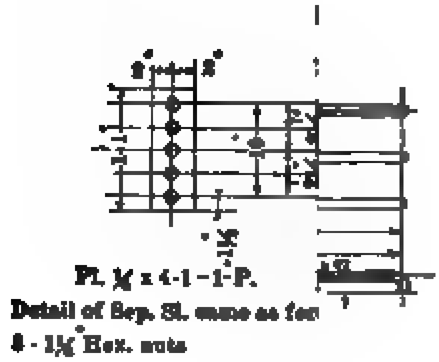
REINFORCING RODS
OF
SECOND - FLOOR GIRDERS.
Mc GRAW BUILDING.
NEW YORK CITY





EAST END

for concrete-steel beams being used. While the parabolic law of variation of intensity of stress in concrete beams results in a trifling economy of material, it is less rational and simple than the usual straight-line law of variation, and the latter is more nearly accurate.

The Building Code of New York does not permit the condition of perfect continuity of beams to govern the design of reinforced concrete floor beams and girders. It is permitted, however, to consider the maximum bending moment of such beams, when uniformly loaded from end to end, as the total load multiplied by one-tenth of the span, rather than one-eighth of the span as would be taken were the beams simply supported at each end. This is a widely used method for continuity, in favor of which much can be said. It is extremely doubtful whether perfect continuity is attained in any case, but it is certain that a material advantage is secured over the condition of a beam simply supported at each end. The one-tenth rule, as it may be called, is a reasonable compromise.

Another condition insisted upon in the design of this building was a metallic provision for taking the end shears of beams and girders. By referring to the plans, there will be observed inclined portions of the round steel reinforcing rods to which attention has already been called. In every case there is sufficient steel in these inclined portions of rods to take the total end shears multiplied by the secant of the inclination rods to a vertical line without stressing the steel to an unsafe extent. While the tension in the steel produced in this manner, ignoring entirely the shearing resistance of the concrete, is higher than would normally be prescribed, it is far below the elastic limit, and forms a safe provision for the entire end shear in case any exigency should arise producing such a break in the concrete as practically to destroy its capacity for shearing resistance. In addition to this condition, there is sufficient concrete also at the ends of beam and girder spans to carry the shear at an intensity of 50 lb. per sq. in. of concrete section as permitted by the New York Building Code. This, also, has been considered one of the essential details of a concrete-steel building designed for a heavy and otherwise fatiguing service.

The floor slabs spanning the spaces between the floor beams are 4 in. thick in the lower floors, carrying the heaviest loads, and 3½ in. thick in all the higher floors. Their reinforcements are ½-in. and ⅝-in. rods, long enough to extend over a number of panels or spans so as

to make these also continuous. Their general design is similar to that of the floor beams and girders. As the distance apart of the centers of the floor beams is about 5 ft. 2 in., the clear span of these floor slabs varies from about 4 ft. to a little more than 4 ft. 4 in., according to the thickness of the adjoining floor beams on either side of the span.

The proper design of the wooden forms or moulds for a concrete-steel building, in order to secure expeditious and economical work, is the most difficult part of the entire undertaking, and the principal improvements to be made in it are those which pertain to perfecting a proper system of construction of the forms and their ready handling. The quantity of lumber required in them, and the carpentry work necessary in making repairs consequent upon their use and re-use for successive floors, and in their supports, constitute far larger items of cost than might at first be supposed. If these costs are to be reduced, as they must be for heavy concrete-steel construction of the best class, the principal study of the engineer must be directed to this particular part of his work. While these ends may not be, and probably have not been, completely attained in this instance, the system of forms used gave excellent results in the quality of the concrete produced, and led to reasonable economy and efficiency. The weight of concrete and the relatively large quantities used in such individual members as beams, girders, and columns make heavy forms imperative and substantial support necessary.

The details of the timber forms for the floor beams and girders where they meet the column forms require especial attention. A proper design of the parts where the floors and columns join will result in great economy in the details of the forms. If the shapes of the exterior surfaces of the concrete are complicated and require careful fittings of the column and floor forms, expensive carpentry work will be required wherever a column pierces a floor, whereas simply shaped concrete surfaces will eliminate that work and greatly expedite the construction. Similarly, it is highly desirable that there shall be as few changes as possible in the exterior dimensions of the columns. If exterior column dimensions could be retained unchanged from basement to roof, it would make possible complete uniformity of the details of column and floor forms throughout the entire building, eliminating a great amount of fitting and carpentry work otherwise unavoidable.

PLATE XXIV.
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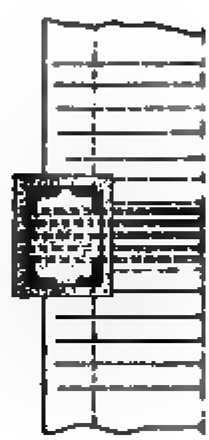
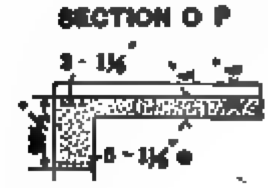
n both ways



½" Rods in both ways

SECTION O P



It is obvious that it is essentially impossible to retain uniform exterior column dimensions throughout the series of floors from the bottom to the top of the building, but the most scrupulous care should be exercised to make these changes as few as possible and in such a way as to reduce to the utmost extent changes of details in the forms.

A reference to the plans will show that the floor forms between the beams consisted of large shallow boxes with truncated corners between the sides and the bottom. They were placed bottom up on stable supports and separated by the thickness of the adjoining floor beams at the sides and by the thickness of the main floor girders at their ends. The bottom of the opening between the adjoining sides of any two of them was then suitably closed with planks or boards so that, when the concrete was finally poured over their tops to the thickness of the floor slabs, the desired paneling of those slabs between the beams and girders was secured. It is imperative, for expediting the work, as well as for economy, that these box forms for the floors shall be constructed so that they may be removed readily after the concrete becomes sufficiently hard. To secure this important result, such forms must be readily collapsible at both ends and sides, and, at the same time, they must be substantial enough to hold the wet concrete without distortion and so well made that they may be handled in removing from one floor and replacing on a higher one without sensible damage. This constitutes one of the most essential points in the design of these forms, which, in this case, were collapsible, although perhaps not as freely as might be desired. When the forms stick to the concrete in the process of removal laborers use sledges and iron bars, driving the latter between the new concrete and the forms and making a fulcrum of the former. This results in seriously marring what might otherwise have been a highly satisfactory concrete surface. The same general observations apply to the forms for the columns. Whenever the art of reinforced concrete construction is brought to the high state of excellence which it must ultimately reach through a proper design of the forms, making their erection, support and removal expeditious and free, the labor bills for the work and the repairs of the forms themselves will be so greatly reduced as to give this class of construction material economic advantage.

The length of time which the forms should remain in place supporting fresh concrete will depend on the temperature, and hence on

the season as well as on the character of the work designed. It is clear that, with the substantial steel reinforcement of the columns of this building, a minimum of time would be sufficient for the column forms, but as it was not convenient to remove the latter until the floor forms were also ready to come down they were all kept in place for at least 19 days. Three entire sets of forms for floors and columns were made, so that, while concrete was being poured for the uppermost floor being constructed, the two stories immediately below were still supported by the timber forms. The lowermost set of forms was then taken down and placed above the freshly formed concrete last put in place. In this manner the forms could be left in place long enough to satisfy the requirements of even the winter season.

The concrete work of the building proper was begun in the basement in September, 1906, and the concrete parapet walls on the roof were completed on April 15th, 1907. These dates show that the work was carried on almost uninterruptedly throughout the winter. A few of the coldest and stormiest days of the winter were sufficiently severe to cause the work to be suspended for the day. When it is remembered that from the latter part of January until the early part of March the weather was phenomenally severe, it is demonstrated by actual experience that reinforced concrete building work may be conducted under proper conditions through a New York winter without material interruption.

After the completion of the lower two or three stories, when the organized force had become accustomed to the character of the work and the sequence of operations required, the average rate of progress, including the delays and occasional interruptions caused by the winter weather, was about 12 calendar days to a story.

From the early part of December to the latter part of March the window openings of the story below the floor in process of construction were closed with canvas, behind which, distributed over the entire floor, salamanders burning coke were constantly kept in operation. These salamanders were to some extent concentrated under the freshly poured concrete. By these means entirely satisfactory temperatures could be maintained, so that the retarding influence of the frost on the setting of the concrete was to a great extent eliminated, except for the fact that occasionally the top surface of the fresh concrete was frozen. The warmest air produced by the salamanders would rise to

and remain in the overhead cellular spaces of the timber floor forms and act there with a high degree of efficiency.

In connection with the operation of the salamanders below the fresh concrete, the top of the latter, as fast as poured, was always protected by a covering of hay or canvas, or both. These protective measures were scrupulously enforced throughout the winter with entirely satisfactory results. Indeed, there was no evidence to be found throughout the whole building to show that any part of the concrete whatever was affected injuriously to the slightest extent by the frost. During a considerable portion of the winter a few salamanders were kept burning in the second floor below the work in progress.

All the construction work of the building was carried on from a high central temporary timber tower running from the basement to a height of nearly 75 ft. above the roof. This timber tower was 31 ft. square and built with 10 by 10-in. yellow pine spliced corner posts properly braced. Each 10 by 10-in. corner stick carried a derrick boom 75 ft. in length. These derricks were first placed low down on the tower, and then raised from time to time to elevations required by the progress of the work. The booms were long enough to command the entire area of the work, and had a sufficient swing or reach to pick up material, including sections of the steel columns, delivered in the street in front of the building, and put it in its proper permanent place. The hoisting engines were placed in the basement, and steel cables ran from them up to the derricks.

It was a question at first whether the cost of this tower and derricks was justified by the amount and character of the work to be done, but they were found to be fully justified and well adapted to their purpose. It was probably as economical and expeditious a method as could have been devised for handling the materials and serving the work. As the building was carried up, the work within the limits of the tower was completed, with the exception of the points where the corner 10 by 10-in. sticks pierced the respective floors where enough free room was left for the operating cables. After the concrete work was finished the tower was taken down through the succeeding floors of the building, and the holes left for the corner posts were filled.

There was nothing unusual about the character of the materials used throughout the building. The material and workmanship of all the steelwork were supplied and manufactured under Cooper's Speci-

fications. The Portland cement used was the Dragon Brand, and it was tested and supplied under the standard specifications recommended by the Special Committee of the American Society of Civil Engineers. The sand, broken stone, and gravel were supplied by different parties about the City of New York. Some of the broken stone came from the north, down the Hudson River, and most of the sand and gravel came from Long Island. Throughout the building proper, ¾-in. broken stone—trap rock and limestone—was used, with the exception of considerable quantities of gravel in which no pieces had a greater maximum diameter than about ¾ in. In some of the larger masses of the retaining walls and other similar parts of the foundation and basement of the building, 1½-in. broken stone was used.

The proportions of the concrete for the entire building were: one of cement, two of sand, and four of broken stone or gravel by volume. The consistency of the concrete was very nearly or quite wet enough to be that termed semi-liquid, so that it was truly "poured" into all forms for columns, walls and floors. Such a consistency of concrete is imperative for reinforced concrete construction of this class. It enables the concrete to form an intimate and dense matrix around the steel reinforcement, and produces a most excellent quality of material. While the concrete was being poured laborers with long thin sticks continually agitated the fresh concrete in order to release all air bubbles and insure a dense and continuous product and the best possible bond with the embedded steel. There was no sensible excess of water in the concrete, but it was practically semi-liquid—too thin even to quake. The results throughout the entire work, in this respect, have proved to be in the highest degree satisfactory. The total quantities of the principal materials used were:

Cement	8 500 bbl.
Sand	3 000 cu. yd.
Broken stone	4 300 cu. yd.
Gravel	1 066 cu. yd.
Steel in latticed angle columns	655 tons.
Steel in round reinforcing rods	507 tons.

SPECIFICATIONS FOR CEMENT AND CONCRETE FOR THE McGRAW BUILDING.

Cement.—All the cement used in this structure shall be true Portland cement of the quality prescribed in the specifications of the Com-

mittee of the American Society of Civil Engineers. The tests required to establish the suitability of the cement will be in accordance with those prescribed in the American Society specifications.

Concrete.—The concrete shall be composed of cement, sand and broken stone, or gravel, mixed with clean water.

The sand may be natural sand or the finer product of the stone crusher. It shall be clean, hard, and preferably of varying sizes, so as to reduce the volume of voids. The gravel or broken stone shall be of varying sizes, free from sensible amounts of clay, loam, or foreign matter. The largest pieces shall not exceed 1½ in. in their largest dimension.

All concrete shall be thoroughly mixed so as to work the cement uniformly through the entire mass. All particles of sand, gravel, or broken stone must be completely coated with cement, and all the voids entirely filled.

All concrete shall be mixed in a machine mixer. The volume of matrix and the aggregate with the requisite quantity of water shall be kept in the mixer long enough to produce the intimate admixture desired. The quantity of water used shall be sufficient to make a wet or even semi-liquid concrete, so that it will readily run or flow into all the small spaces to be filled around all classes of steel reinforcement, whether in the floors or in the columns. This concrete shall be too wet to ram, but, while being poured and immediately thereafter, it must be actively agitated by long thin rods so as to expel all entrained air and produce a continuous and intimate bond with the steel embedded in it.

All concrete for the building proper, *i. e.,* above the foundations, shall be composed of such proportions of cement, sand, and gravel, or broken stone, as will make a perfectly solid mass, with a little surplus of cement over that required to fill the voids. The proportions of this mixture will be equivalent to 1 volume of cement, 2 volumes of sand, and 4 volumes of gravel, or broken stone.

In these provisions for the concrete it is the intention to take advantage of balanced sand, gravel, or broken stone, *i. e.,* to use varying sizes for the purpose of decreasing the voids, and using less cement to secure the best results. It will probably be necessary, therefore, to experiment with different proportions of different sizes of sand and gravel, or broken stone, in order to ascertain the best mixture of the available materials at hand to secure the desired ends.

The largest pieces of the aggregate, *i. e.,* gravel, or broken stone, for the building proper shall not exceed ¾ in. in their greatest dimension. For the retaining or area walls around the basement of the building, and in foundation masses, the maximum size of broken stone or gravel in the aggregate may be 1½ in.

The proportions of the concrete for the retaining or area walls and foundation masses shall be 1 volume of cement, 3 volumes of sand, and 5 volumes of gravel, or broken stone, the aggregate being balanced or graded so as to reduce to a minimum the voids to be filled with the cement.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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INVAR (NICKEL-STEEL) TAPES ON THE MEASUREMENT OF SIX PRIMARY BASE LINES.

By Owen B. French, M. Am. Soc. C. E.

To be Presented December 4th, 1907.

Until near the end of the last century, geodesists considered some form of bar apparatus necessary for the accurate measurement of primary base lines. The use of any bar apparatus is very expensive, hence, when it became apparent that frequent bases were required in a triangulation scheme, a more economical form of measuring apparatus was necessary. As the question of economy would undoubtedly be solved by the use of long tapes or wires, many attempts were made to devise some means of securing a satisfactory degree of accuracy with apparatus of this type. Long steel tapes or wires had been in use for many years for measuring purposes, but, until about 1890, they were not considered accurate enough for primary measurement. Although many had investigated the use of tapes for accurate measurement, to a greater or less extent, one of the first to make a successful investigation was Professor R. S. Woodward, while he was an Assistant on the United States Coast and Geodetic Survey.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

The results of his work and their discussion, together with the mathematical formula required for the general use of tapes, may be found in Appendix 8 of the Coast and Geodetic Survey Report for 1892.*

Previous Work with Steel Tapes.—The long steel tapes used by Professor Woodward in his investigations have been used since in the measurement of a number of base lines by the Coast and Geodetic Survey. The most important work of this character was the measurement of nine base lines along the 98th meridian, by Mr. A. L. Baldwin, in 1900.† A direct comparison between the measurements with bars and steel tapes was made on each of the nine bases. The duplex bar apparatus—one of the best forms of bar apparatus known—was used, and also both 50 and 100-m. steel tapes. The results of this work demonstrated that steel tapes, when used at night, and standardized under the same conditions that prevail during the base measures, gave practically the same degree of accuracy as the duplex apparatus, for about one-third of the cost. This work also demonstrated that the gain, either in accuracy or economy, by the use of a tape more than 50 m. long, was so small as to fail to offset the gain in convenience of manipulation in the field possessed by the shorter tape. Consequently, the Coast and Geodetic Survey, until recently, has considered the 50-m. steel tape the best form of base-measuring apparatus, if used at night, when the temperature of the tape can be obtained very accurately.

Invar, or Nickel-Steel Alloy.—When, a few years ago, Dr. C. E. Guillaume, Assistant Director of the International Bureau of Weights and Measures, near Paris, discovered an alloy of nickel and steel which possessed a small coefficient of expansion, its use for base measurement was immediately suggested, as the effect of temperature errors would undoubtedly be greatly reduced by using such a metal. This alloy is made near Paris by a secret process, and contains about 36% of nickel. It has been given the name of "invar," a word derived from the same root as the word invariable, and having a similar meaning.

Guillaume's investigations of the properties of this alloy have been quite extensive. The results of his work have been published from time to time in such scientific publications as *Bulletins des Séances de la Société Française de Physique, Archives des Sciences, Comptes*

* "On the Measurement of the Holton Base, Holton, Ripley County, Indiana, and the St. Albans Base, Kanawha County, West Virginia."

† "On the Measurement of Nine Bases Along the Ninety-eighth Meridian," Apx. 8, U. S. Coast and Geodetic Survey Report, 1901, p. 229.

Rendus, Journal de Physique, Metallographist, etc., in addition to the publications of the International Bureau of Weights and Measures.

Guillaume's investigations extend over a period of several years, and, in so far as they apply to base measurement, have been made with bars, or wires, usually 24 m. long.

U. S. Coast and Geodetic Survey Invar Tapes.—The use of wires instead of tapes has not been considered advisable on the Coast and Geodetic Survey, the objections to wires being considered of more consequence than the objections to tapes.

As soon as Guillaume's investigations with the invar wires had advanced far enough to prove that the metal is comparatively stable, the Coast and Geodetic Survey decided to test some tapes of this alloy. Although invar wires could be obtained with little difficulty, no invar tapes could be secured until December, 1905, when they were purchased in London, England.

These invar tapes are about 52 m. (171 ft.) long, 6.3 mm. (0.25 in.) wide, and 0.5 mm. (0.02 in.) thick, with a mass of about 25 g. per m. of length (0.027 oz. per ft. of length). They are slightly longer and heavier than the steel tapes used by the U. S. Coast and Geodetic Survey, the mass of the latter being about 20 g. per m. of length.

The invar tapes are considerably brighter than the steel tapes, being more nearly like nickel in appearance. Although they are less easily oxidized than steel tapes, they require almost as much care in order to keep them free from rust. The metal is softer, more easily bent, and less elastic than steel.

When these tapes were laid, without tension, upon a flat surface, they appeared crooked, being full of small bends in all directions. These bends were not large enough, however, to cause any part of the tape to be more than about ½ in. from a straight line. The large bends were removed from all tapes used for base measurement, before beginning the standardization.

When the tapes were stretched under a tension of 15 kg. (the tension used on all the measures), the remaining small bends were practically eliminated, although in certain lights numerous minute irregularities were distinctly visible. These small irregularities were so nearly the same every time the tape was stretched under a tension of 15 kg., that the length of the tape was practically constant. This was proven in the standardization of these tapes.

The measurement of several primary base lines had been postponed a year or more by the Coast and Geodetic Survey, in hope of securing some of these invar tapes; hence, when they were received, preparations for the measurement of these bases were immediately begun.

Several of the invar tapes were prepared for measuring purposes, in the same manner as the steel tapes, by the Instrument Division of the Coast and Geodetic Survey. Small silver sleeves were riveted rigidly to each tape near either end, to carry the graduation marks, the distance between the two marks on a tape being very nearly 50 m.

An aluminum reel, 16 in. in diameter, was made for each tape. The size of these reels was not considered of sufficient consequence to warrant special investigation, hence it was fixed in accordance with a statement made by Mr. Baugh when transmitting the tapes.

The fact that these reels are not small enough to affect the length of a tape was proved during the standardization by reeling and unreeling one tape one hundred times on several different days, no change in its length being noticeable.

Investigations of the Properties of Invar Tapes.—Notwithstanding the fact that Guillaume's investigations with invar wires were quite extensive and satisfactory, it was considered best to make experiments enough with these tapes to be certain that they did not possess properties which would affect materially the accuracy of any measures that might be made with them. Consequently, several short pieces of the tapes were tested, at the National Bureau of Standards, in order to find:

First.—The tensile strength;

Second.—The yield point; and

Third.—Whether the continued application and removal of small loads affected the length of the tape.

The tensile strength was found to be about 100 000 lb. per sq. in. (practically one-half that of ordinary tapes), a load of more than 450 lb. being required to break the specimens. The yield point, determined with a Henning mirror extensometer, was about 70% of the tensile strength.

One specimen had a load of 40 lb. suspended from it for 60 hours, without showing any change in length. Loads up to 60 lb. were applied and removed on one of the specimens many times, the lengths corresponding to the same loads being practically identical.

The results of these experiments were very satisfactory; and no properties derogatory to the use of these tapes for measuring purposes were discovered.

Disadvantages of Steel Tapes.—Steel tapes must be standardized in the field and used at night in order to obtain the accuracy required for the measurement of primary base lines. The cost of the measurement is increased very considerably on this account. As these conditions are necessary, owing to the uncertainty in the determination of the temperature of the tape, it was hoped that this expense could be eliminated by using a metal which possessed a small coefficient of expansion. Consequently, the invar tapes were standardized at the Bureau of Standards both before and after the field measures.

Night measures are objectionable for many reasons: The necessity for illumination causes a loss in accuracy and also a loss in speed, thus increasing the cost of the work. Therefore, the invar tapes were used during daylight hours only.

Owing to the fact that the invar tapes were unknown, and that there was a possibility of their proving too unstable for accurate work, it was decided to make a complete measurement of all the bases with the steel tapes as well as with the invar tapes, thus insuring a satisfactory determination of the lengths of the bases and affording a means of studying the relative action of the two kinds of tapes.

Standardization.—The steel tapes were used entirely at night and standardized in the field just before and just after the measurement of the six bases. The invar tapes were standardized at the Bureau of Standards.

All the tapes were standardized in practically the same manner, by comparing them many times with a 50-m. comparator, the length of which was obtained with the iced-bar apparatus.

The 50-m. comparator used at the Bureau of Standards is located in a tunnel about 2½ m. high and wide, and 52 m. long. Along one wall of this tunnel are a number of pipes through which brine, at a temperature of —10°, may be pumped to get low temperatures. The iced bar used for this work is the one designed by Professor Woodward, and described in the Coast and Geodetic Survey Report for 1892. It is a steel bar, a little more than 5 m. long, the measure being the distance between two fine lines cut into platinum iridium plugs, one near each end of the bar. The bar is supported by adjustable bolts

in a V-trough, the trough resting upon trucks also adjustable. A track was built in the floor of the tunnel for these trucks to run upon so that the bar could be moved along rapidly. Microscopes for holding the measure while the bar was being run ahead were mounted upon heavy iron arms, one end of each being attached, in an adjustable manner, to the top of a stone post. These posts were 5 m. apart, the length of the bar. A hole was cut through the top of each post to permit the light from an electric bulb, suspended back of the post, to supply the illumination for the microscope. Each stone post was mounted upon a concrete pier.

The microscopes were carefully aligned by a fine wire stretched between the end microscopes and near the foci of all. The heights of the microscopes were such that their foci were nearly in a straight line which was practically horizontal.

The inclination of the bar in each position (the end marks of the bar being in the foci of the microscopes) was determined with a sector attached to the side of the trough, thus giving data for the elimination of the effect of the small differences in height between the foci of the microscopes.

The ends of the comparator were marked by spherical-headed bolts set in the concrete piers which support the end microscope posts. These marks were directly under the end microscopes which were referred to the end marks frequently during the standardization by the cut-off cylinders used heretofore.

The bar was aligned and leveled in the usual manner, the trough being kept as full of crushed ice as possible during each operation. The bar was usually surrounded with ice at least a half hour before beginning the measurement.

A determination of the length of the comparator consisted of at least two measures with the iced bar in opposite directions.

When making the tape comparisons at the Bureau of Standards, a determination of the length of the comparator was made at the beginning and also at the end of each day's work. When at work in the field such a determination was made before beginning the tape comparisons, after their completion, and at intermediate times, if necessary to make the interval between the tape comparisons and comparator determination less than 24 hours.

The lengths of the tapes were obtained by stretching them under

the end microscopes of the comparator, always supporting and handling them in practically the same manner as they were to be used in the field. The invar and steel tapes were handled in exactly the same manner. The tape was supported at the graduation marks and also at one point in the middle in line with the end supports. A tension of 15 kg. was used, indicated by a spring balance having a dial with a hand working over its face. A complete revolution corresponded to 5 kg. The tension could be read to about 10 g. without difficulty.

A thermometer with a metal back was fastened 1 m. from the graduation mark (and toward the middle), at each end of the tape. These were always read immediately after making pointings upon the graduation marks of a tape.

During standardization the rear end of the tape was held rigidly by an adjustable clamp. The forward or balance end was held by an adjustable ratchet device, at the Bureau of Standards, and by the tape stretcher used on the base measurement, for the field standardization.

A determination of the length of the tape consisted of two simultaneous pointings by the two observers on the graduation marks of the tape, followed immediately by two more after the observers had exchanged places.

An ordinary day's work was found to be a double comparison of from six to eight tapes, with an iced-bar determination of the length of the comparator, both before and after. During February, 1906, before beginning the base measures, twelve or thirteen comparisons were obtained for each of the six invar tapes, six comparisons at a temperature of about $+4°$ cent., and the remainder at about $+25°$ cent. After the base measures, in October, 1906, five of these tapes were again standardized, four comparisons being obtained for each.

The results of the standardization for the five invar tapes are as follows, each temperature being the mean of all the observed temperatures for that tape, as the length is the mean of all the observed lengths:

	Temperature, in degrees, cent.	Length, in millimeters.	
Tape No. 437.			
February, 1906.........	14.24	+ 7.816	
October, 1906..........	25.62	+ 8.079	
Mean...... .	19.93	7.947	± 0.007 mm.

	Temperature, in degrees, cent.	Length, in millimeters.	
Tape No. 438.			
February, 1906.........	14.26	+ 8.057	
October, 1906..........	25.60	+ 8.380	
Mean........	19.93	+ 8.218	± 0.009 mm.
Tape No. 439.			
February, 1906.........	14.24	+ 6.578	
October, 1906..........	25.60	+ 6.864	
Mean........	19.92	+ 6.721	± 0.007 mm.
Tape No. 440.			
February, 1906.........	14.38	+ 9.418	
October, 1906..........	25.70	+ 9.702	
Mean........	20.04	+ 9.560	± 0.008 mm.
Tape No. 442.			
February, 1906.........	14.16	+ 9.218	
October, 1906..........	25.45	+ 9.548	
Mean........	19.80	+ 9.383	± 0.010 mm.

Table 1 shows the individual values for Tape No. 440, and is a fair sample of the manner in which the results agree: .

TABLE 1.—INDIVIDUAL VALUES OF INVAR TAPE NO. 440.

Date.	Temperature in degrees, cent.	Observed length 50 m., in millimeters.	Computed length 50 m., in millimeters.	Computed minus observed length, in millimeters.
1906.				
Feb. 10...............	27.8	+ 9 666	+ 9.696	+ 0.030
" 12...............	4.4	9.208	9.268	+ 0.060
" 12...............	4.8	9.199	9.266	+ 0.067
" 13...............	3.9	9.195	9.258	+ 0.063
" 13...............	4.1	9.186	9.262	+ 0.076
" 15...............	3.3	9.225	9.247	+ 0.022
" 15...............	2.2	9.287	9.227	— 0.060
" 17...............	24.5	9.587	9.643	+ 0.056
" 17...............	24.6	9.615	9.645	+ 0.030
" 19...............	25.7	9.650	9.666	+ 0.016
" 19...............	24.6	9.616	9.645	+ 0.029
Mar. 1...............	24.1	9.600	9.636	+ 0.036
" 1...............	24.6	9.596	9.645	+ 0.049
Mean...............	14.38	+ 9.418	....	....
Oct. 4...............	25.7	+ 9.716	9.666	— 0.050
" 4...............	25.8	9.686	9.668	— 0.018
" 5...............	25.4	9.685	9.660	— 0.025
" 5...............	25.9	+ 9.721	9.670	— 0.051
Mean...............	25.70	+ 9.702		
Final Mean..........	20.04	+ 9.560 ± 0.008		

The quantities in the column headed "Computed" were obtained from the final mean by reducing it to the temperature of the individual values. The probable error was computed from the residuals given in the last column.

By reducing all the values obtained in the February standardization to the temperature of the October standardization, it was found that there was a slight lengthening of all the tapes during this period. However, as there are residuals of both signs in the February work, at least a part of this difference may be apparent rather than actual. It averages about 1 part in 800 000 for the five tapes, the greatest being 1 part in 617 000. If this change took place uniformly, the mean of the two standardizations gives values from which the lengths of the bases are obtained very accurately. Even if it were a sudden change, the error on any base from this source could not be more than 1 part in 1 600 000, and might be much less. It was probably a more or less gradual change, as there was nothing in the measures to indicate any sudden change. It may have been due to a change in the molecules of the tape itself, but is more likely to have been a straightening out of the many small bends in the tapes. If the latter, it may have been either a gradual change or a sudden one, although the former is the more probable.

Tapes Nos. 437 and 442 were never used, except for the comparisons. Tape No. 437 was taken into the field, but was not used on the base measures. Tape No. 442 was not even taken into the field. The large bends were not removed from Tape No. 442 before standardizing it, and the graduation marks were very irregular, hence its change is probably due partly to these two conditions. As the largest change was only 0.08 mm. per tape length, a quantity barely perceptible to the naked eye, it is certainly not of serious consequence in any case. Steel tapes have been found to change length more than this.

Coefficients of Expansion.—The coefficients of expansion for these tapes were computed from the February observations, the large range in temperatures having been secured for this purpose. During this work at the Bureau of Standards, four steel tapes were also compared for the purpose of getting their coefficients of expansion. Table 2 shows the results obtained for all the tapes:

These coefficients for the invar tapes are very small, being practically one-twenty-eighth of steel tapes. They are about one-half those

of the wires used in the base measurement through the Simplon Tunnel, by Guillaume, thus showing that they are probably smaller than those usually obtained for this alloy.

TABLE 2.

Tape Number.	Expansion per degree centigrade per 50 m	Probable Error.	Coefficient per unit length per degree centigrade.
Invar No. 437	0.0207	±0.0009	0.000 000 41
" " 438	0.0213	0.0008	0.000 000 43
" " 439	0.0203	0.0006	0.000 000 41
" " 440	0.0187	0.0006	0.000 000 37
" " 442	0.0220	0.0009	0.000 000 44
Steel No. 403	0.568	±0.003	0.000 011 4
" " 404	0.568	0.003	0.000 011 4
" " 405	0.569	0.004	0.000 011 4
" " 406	0.565	0.003	0.000 011 3

Bases Measured.—Early in March, 1906, the party left Washington, D. C., to measure six base lines. The first measured was Point Isabel Base, in Southern Texas, near the mouth of the Rio Grande River; second, Willamette Base, in the Willamette Valley, Oregon; third, Tacoma Base, near Tacoma, Wash.; fourth, Stephen Base, near Stephen, Minn.; fifth, Brown Valley Base, South Dakota, near Brown Valley, Minn.; and, last, Royalton Base, near Royalton, Minn. The first, fourth and fifth bases control part of the triangulation along the 98th meridian; the two on the Pacific Coast control the main scheme along that coast between the 39th-parallel triangulation and the Puget Sound work. The last base controls, in part, the triangulation which connects the 98th-meridian scheme with the triangulation of the Great Lakes near Duluth.

All six bases were measured with three steel tapes and also with three invar tapes, each tape being used on about two-thirds of each base. Two complete measures of each base were made with the steel tapes and two with the invar, the steel tapes being used at night only and the invar in the daylight. The measures were arranged so that a complete inter-comparison of all the tapes was obtained on each base.

Field Standardization.—The steel tapes were standardized at the first and also at the last base measured. A 50-m. comparator was built at each of these places, and its length was determined with the iced bar in the same manner as at the Bureau of Standards. The method

of making the tape comparisons was the same as that used at the Bureau of Standards, except that the regular tape stretcher used in the base measures was used at the forward end on the field standardization. Two comparisons were obtained for each of the steel tapes, on each of two nights, at both standardizations, or eight comparisons in all for each tape.

Adopted Lengths of All Tapes.—The adopted lengths and other data for the steel tapes, as derived from the field comparisons, are given in Table 3. The coefficient of expansion was obtained from the work at the Bureau of Standards. The table also gives the adopted lengths and other data for the invar tapes as obtained from the observations at the Bureau of Standards, which have been previously described.

TABLE 3.

STEEL TAPES.

		mm.	mm.	Degrees.
T_{248}	= 50 m. +	3.51	+ 0.527	$(t - 20.62)$
	±	0.010	± 0.003	
T_{403}	= 50 m. +	12.12	+ 0.568	$(t - 20.59)$
	±	0.024	± 0.003	
T_{405}	= 50 m. +	12.56	+ 0.569	$(t - 20.74)$
	±	0.017	± 0.004	
T_{406}	= 50 m. +	12.34	+ 0.565	$(t - 20.88)$
	±	0.021	± 0.003	

INVAR TAPES.

		mm.	mm.	Degrees.
T_{437}	= 50 m. +	7.947	+ 0.0207	$(t - 19.93)$
	±	0.007	± 0.0009	
T_{438}	= 50 m. +	8.218	+ 0.0213	$(t - 19.93)$
	±	0.009	± 0.0008	
T_{439}	= 50 m. +	6.721	+ 0.0203	$(t - 19.92)$
	±	0.007	± 0.0006	
T_{440}	= 50 m. +	9.560	+ 0.0187	$(t - 20.04)$
	±	0.008	± 0.0006	
T_{442}	= 50 m. +	9.383	+ 0.0220	$(t - 19.80)$
	±	0.010	± 0.0009	

Field Procedure.—The preparation of the base lines for measurement was practically the same as for previous base measurements with steel tapes. Posts, 4 by 4 in., were driven every 50 m. along the line, with posts 2 by 4 in. midway between them. A nail, for the middle support of the tape, was driven into each of the 2 by 4-in. posts, in line

with the tops of the adjoining 4 by 4-in. posts, or raised enough so that the tape would clear the ground or other objects. In this case its height was determined while running the levels over the base. All these posts were carefully aligned with a theodolite. Forward sights only were used, and posts were rarely set on more than 300 m. from one position of the instrument. There was probably no tape length that was out of parallelism to the base by as much as 1 cm., thus eliminating errors from this source.

A forward and backward line of levels was run over each base to determine the height of each 4 by 4-in. post and all 2 by 4-in. posts which were not on grade with the tops of adjoining 4 by 4-in. posts. The difference in height of any two adjoining posts was probably obtained within 1 cm., hence errors from this source are also negligible. The corrections for grade were obtained from a table prepared for the argument, difference in height, h, using the formula:

$$c = -\frac{h^2}{2s} - \frac{h^4}{8s^3} - \frac{h^6}{16s^5} -, \text{ etc.},$$

s in this case being 50 m.

Copper strips, of the same thickness as the graduation sleeves on the tapes, were nailed to the tops of the 4 by 4-in. posts to hold the marks for the measures. Each base was divided into sections about 1 km. in length. The various measures of a section were all referred to the same lines on the copper strips of the terminal posts, hence are directly comparable.

Heavier posts were set very solidly at the ends of the sections to hold the measure for several days, if necessary. Only complete sections were measured at one time, thus the 4 by 4-in. posts were not depended upon to hold the measure for more than a few minutes.

The tapes were stretched over the 4 by 4-in. posts, with a thermometer attached to the top, in the same manner as in the standardization. The rear end was held by a small steel bar. The forward end was attached to the hook of the balance, which was fastened to the stretcher by a gimbal attachment with counterpoise, so that the balance could always be kept horizontal. A steel point was fastened at the lower end of the stretcher bar, and a quick and accurate adjustment for the height of the tape was made without using the screw adjustment, by merely pressing the stretcher into the ground more or less as might be required.

All 4 by 4-in. posts were set at a uniform height above the ground (about ½ m.), so that no time would be lost during the measure in adjusting the tape stretcher.

Party Organization.—The measuring party was composed of two observers, two tape stretchers, one recorder, and two men to support the middle of the tape while it was being carried forward, seven in all. The first three bases were prepared by the measuring party, but the last three were prepared by a separate party, consisting of five men. This party prepared three bases, aggregating a length of 27 km., in 17 working days. This time includes delays on account of weather and travel between bases. The latter required four days. On about a kilometer of one base, the posts were set in a pond where the water was about 2 ft. deep, and each post in the water was double braced in order to insure its stability, thus delaying the preparations very materially. This party had no difficulty in preparing between 3 and 4 km. per day, under ordinary conditions. When the preparation party finished with a base, everything was ready for beginning the measures. The copper marking strips were usually nailed to the tops of the posts during the first measure.

Speed of Measurement.—A single measurement of 12 km. was found to be an ordinary day's work, when half of it was made at night. Occasionally, 14 km., or more, were measured in one day. This, however, occurred only when the work had been delayed from some cause, and was too much to be maintained for any length of time. The speed with which the measurement progressed was a trifle more rapid with the invar than with the steel tapes. After the party acquired some experience, a speed of more than 2 km. per hour was ordinarily maintained. The average speed for the invar measures on the last base was 2.6 km. per hour, the whole party being well trained by this time. No attempt was made merely to acquire speed, a tape length never being marked until everything was apparently steady and correct.

Record and Computation.—The record kept on this work was very simple. It consisted principally of two thermometer readings for each tape length, with an occasional set-up or set-back, made in order to keep the marks on the copper marking strips. Notes as to the condition of the weather, or the occurrence of anything that might affect the measures, were inserted whenever needed. In making the computations the average temperature for each section was used to deter-

mine the average length of the tape during the measurement of that section.

Table 4 gives the results of the measures for each section of the Brown Valley Base, and is a fair sample of the form of computation and differences between the results for the individual sections, as obtained on all the bases.

In Table 4 the time is given in hours and tenths. All measures with steel tapes were made at night, and all measures with invar tapes in the daytime, hence it is unnecessary to insert A. M. or P. M. The columns headed "Weather," "Wind," "Temperature," "Temperature, rising or falling," and "Temperature range" are inserted to permit the study of possible sources of errors. The abbreviations used in these columns are: R = rising; F = falling, for temperature; F = fair; C = cloudy; P = Partly cloudy; R = rain; M = mist; and D = dew, for weather conditions; L = light; M = moderate; and H = fresh, for wind, with the usual abbreviations for its direction. The temperature range is given to tenths of degrees for the steel tapes, but only to degrees for the invar tapes, owing to their smaller coefficients of expansion.

Column 6 shows the average temperatures for each measurement of a section, corrected for thermometer errors. Column 11 gives the corrections to the tapes due to differences between this temperature of observation and that of standardization for the particular tape. Column 12 gives the grade corrections as obtained from the difference in heights between adjoining posts, as previously mentioned in this paper. Column 13 gives the reduction to sea level obtained from the average height of the section, h, using the formula

$$c = -s\frac{h}{\rho} + s\frac{h^2}{\rho^2} - s\frac{h^3}{\rho^3} +, \text{etc.},$$

s being the length of the section, and ρ the radius of curvature of the earth for this base line. Column 14 gives the algebraic sums of the set-ups and set-backs for each measure of the sections. Column 15 gives the tape corrections for the sections, obtained by multiplying the excess of the length of the tape over 50 m. by the number of tape lengths in the section. Column 16 shows the algebraic sum of Columns 11 to 15. These quantities are the results of the individual measures for the various sections. Column 17 shows the lengths of the sections as determined with the steel tapes, and Column 18, the lengths as

determined with the invar tapes. Column 19 gives the residuals for the various measures of the sections, not combining the invar and steel results. Column 20 shows the differences between the invar and steel measures of the various sections.

Computation of Probable Errors.—The probable error for the base was determined as follows: The probable error of each section was determined from the residuals of Column 19, keeping the measures with the steel and invar tapes separate. These values were combined with the probable errors of the tapes, the latter being obtained by multiplying the probable error of one length of the tape, given with the adopted lengths of tapes, by the number of tape lengths in the section.

The probable error of the length of the base, given by the steel tapes, was obtained by taking the square root of the sum of the squares of the probable errors of all the sections obtained from the measures with steel tapes, and the probable error of the length from the measures with the invar tapes, by a similar combination of the probable errors of the sections obtained from measures with invar tapes.

Probable error of measures with steel tapes, Brown Valley Base .... ± 4.98 mm.
Probable error of measures with invar tapes, Brown Valley Base .... ± 2.05 mm.

These values were then combined with the probable errors due to the probable errors of the coefficients of expansion. The latter were obtained by taking the sum of all the temperature differences between the observed and standard temperatures of the tapes on the base and multiplying this by the average probable error of the coefficients of expansion of the tapes, these probable errors being nearly equal.

The probable error due to probable errors of coefficients of expansion for steel tapes was.................. ± 2.46 mm.

The probable error due to probable errors of coefficients of expansion for invar tapes was................. ± 0.22 mm.

Combining these with the values already given we have:

Probable error due to measurements and coefficients:

Steel tapes .... ± 5.55 mm.
Invar tapes .... ± 2.06 mm.
Weighted mean, steel and invar tapes...... ± 2.09 mm.

TABLE 4.—RESULTS OF MEASURES

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Number of section and posts.	Date.	Time of day.	Direction of measure.	Number of tape.	Mean Temperature.	Temperature, Range.	Temperature. Rising or Falling.	Weather.	Wind.	Temperature.
	1906.	Hour.			Degrees.	Degrees.				
1 S. E. B. to 20...	June 27	9.7	SE.	440	24.33	6	RF	P	LS	+0.0016
	June 27	10.2	NW.	438	25.28	5	RF	P	LS	+0.0023
	June 27	9.0	SE.	406	21.05	0.6	RF	PD	......	+0.0019
	June 27	9.5	NW.	403	21.20	0.9	F	PD	......	+0.0069
2 20 to 40.........	June 27	9.1	SE.	440	22.77	6	R	P	LS	+0.0010
	June 27	10.7	NW.	438	26.40	6	RF	P	LS	+0.0028
	June 27	8.5	SE.	406	20.39	1.4	FR	PD	......	−0.0055
	June 27	10.0	NW.	403	20.10	1.0	F	PD	......	−0.0056
3 40 to 60.........	June 26, 27	......	SE.	440	21.15	3	RF	P	LN	+0.0004
	June 27	11.0	NW.	438	24.60	3	F	P	LN	+0.0013
	June 27	3.2	NW.	439	24.46	3	RF	P	LN	+0.0006
	June 29, 27	......	SE.	406	19.68	2.0	F	PD	......	−0.0136
	June 29	10.5	NW.	403	19.57	0.6	FR	PD	......	−0.0076
	June 29	9.0	NW.	405	15.98	0.6	RF	PD	......	−0.0190
4 60 to 80.........	June 26	4.0	SE.	440	22.90	5	FR	P	LN	+0.0011
	June 26	3.6	NW.	439	25.02	5	RF	P	LN	+0.0021
	June 29	9.9	SE.	406	14.72	3.0	RF	DF	LE	−0.0696
	June 29	9.5	NW.	405	13.69	4.1	F	FD	LE	−0.0802
5 80 to 100........	June 26	4.4	NW.	439	25.50	5	RF	P	LN	+0.0023
	June 26	5.2	SE.	440	21.82	3	RFR	P	LN	+0.0018
	June 29	10.0	NW.	405	12.53	1.7	FR	FD	LE	−0.0934
	June 29	11.0	SE.	406	13.16	1.8	FR	FD	LE	−0.0872
6 100 to 105.......	June 26	4.6	NW.	439	24.45	3	R	P	LN	+0.0005
	June 26	5.0	SE.	440	25.46	2	F	P	LN	+0.0005
	June 29	10.3	NW.	405	12.02	0.4	R	FD	LE	−0.0232
	June 29	10.5	SE.	406	12.76	0.5	R	FD	LE	−0.0207
7 105 to 125.......	June 26	9.0	NW.	438	18.28	3	FR	P	L	−0.0007
	June 26	11.4	SE.	439	20.71	6	RF	P	L	+0.0003
	June 30	8.5	NW.	405	11.20	1.4	FR	FD	LNE	−0.1066
	June 30	10.8	SE.	403	8.83	1.5	FR	FD	LNE	−0.1336
8 25 to 145.......	June 26	9.5	NW.	438	19.66	6	RF	P	L	−0.0001
	June 26	10.9	SE.	439	22.32	7	F	P	L	+0.0010
	June 30	8.9	NW.	405	10.47	1.3	FR	FD	LNE	−0.1169
	June 30	10.4	SE.	403	9.52	1.3	FR	FD	LNE	−0.1258
9 145 to N. W. B...	June 26	9.9	NW.	438	20.96	5	RF	P	L	+0.0004
	June 26	10.5	SE.	439	22.34	6	FR	P	L	+0.0010
	June 30	9.4	NW.	405	9.56	0.9	FR	FD	LNE	−0.1272
	June 30	9.9	SE.	403	9.64	1.0	FR	FD	LNE	−0.1244

* This section was measured in part with each of the tapes given.
† Full or half-tape lengths did not fit between the ends of this section, hence, the fractional

OF BROWN VALLEY BASE.

CORRECTIONS.								
(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Grade.	Sea Level.	Set-up or Set-back.	Tape Length.	Corrected length of section.	Mean Length, Steel tapes.	Mean Length, Invar tapes.	Residual, Mean: Observed.	Difference, Invar: Steel.
				mm.	mm.	mm.		
−0.0806	−0.0542	+0.0389	+0.1912	1 000.0970			−0.8	
		+0.0644	+0.1644	.0964		1 000.0967	+0.8	
		−0.0118	+0.2468	.1027			−1.5	
		−0.0148	+0.2424	.0998	1 000.1012		+1.4	−4.5
−0.0148	−0.0538	−0.0843	+0.1912	1 000.0898		1 000.0897	−0.1	
		−0.0595	+0.1644	.0896			+0.1	
		−0.1335	+0.2468	.0897			+0.3	
		−0.1285	+0.2424	.0402	1 000.0400		−0.2	−0.3
−0.0130	−0.0541	−0.1290	+0.1912	999.9955			0.0	
		−0.0932	+0.1060 *	.9955		999.9955	0.0	
			+0.0470 *					
		−0.1679	+0.2468	.9962			−1.1	
		−0.1559	+0.1576 *	.9959			+1.2	
			+0.0879 *		999.9971			−1.6
−0.0126	−0.0641	−0.0292	+0.1912	1 000.0964			+0.9	
		+0.0284	+0.1344	.0982		1 000.0973	−0.9	
		−0.0166	+0.2468	.0989			−0.8	
		−0.0110	+0.2512	.0988	1 000.0936		+0.3	+3.7
−0.0104	−0.0548	+0.0215	+0.1344	1 000.0931			−1.0	
		−0.0869	+0.1912	.0910		1 000.0921	+1.1	
		−0.0026	+0.2512	.0901			+0.5	
		−0.0034	+0.2468	.0911	1 000.0906		−0.5	+1.5
−0.0061	−0.0122	+0.0066	+0.0308	222.9643†			+0.2	
		−0.0057	+0.0430	.9647		222.9645†	−0.2	
		+0.0024	+0.0565	.9636†			0.0	
		+0.0018	+0.0556	.9636	222.9635†		0.0	+0.9
−0.0298	−0.0544	+0.0297	+0.1644	1 000.1092			+1.8	
		+0.0628	+0.1344	.1128		1 000.1110	−1.8	
		+0.0464	+0.2512	.1048			+2.9	
		+0.0860	+0.2424	.1106	1 000.1077		−2.9	+3.3
−0.0419	−0.0547	+0.0859	+0.1644	1 000.1036			+1.9	
		+0.0686	+0.1344	.1074		1 000.1055	−1.9	
		+0.0638	+0.2512	.1010			+3.3	
		+0.08 6	+0.2424	.1076	1 000.1043		−3.3	+1.2
−0.0642	−0.0553	+0.0222	+0.1644	1 000.0675			−0.2	
		+0.0512	+0.1344	.0671		1 000.0673	+0.2	
		+0.0614	+0.2512	.0659			+5.4	
		+0.0783	+0.2424	.0768	1 000.0713		−5.5	−4.0

tape length (−2.0548), measured with a 3-m. bar, has been included in these lengths

The probable errors given so far do not include the probable error in the determination of the length of the comparator. This was practically ± 0.014 mm. As the values for the tapes depend upon two standardizations, we can take $\frac{1}{2} \sqrt{2\,(0.014)^2} = \pm\ 0.010$ mm. as the probable error per tape length, resulting from the uncertainty in the length of the comparator.

As there were 164 tape lengths in the Brown Valley Base, the effect of the probable error of the comparator is $164 \times \pm\ 0.010 = \pm\ 1.64$ mm. This, combined with the last value obtained, gives the final probable error of the Brown Valley Base, ± 2.83 mm. or 1 part in 2 910 000.

This includes all known sources of error throughout all the operations necessary to obtain the length of the base in terms of the international meter.

Length of Bases.—The final lengths of the six base lines, together with their logarithms and probable errors, all computed in the same manner as described above, are given in Table 5.

TABLE 5.

Base.	Length.		Probable error.
	Meters.	Logarithm.	
Point Isabel.......	7 384.9220	3.8683459 ± 2	± 3.02 mm., or 1 part in 2 450 000
Willamette........	14 019.3781	4.1467287 ± 1	4.09 " " 1 " " 3 430 000
Tacoma...........	12 055.5701	4.0811877 ± 2	3.99 " " 1 " " 3 020 000
Stephen...........	9 221.8333	3.9648173 ± 2	4.25 " " 1 " " 2 170 000
Brown Valley.....	8 223.5695	3.9150604 ± 1	2.83 " " 1 " " 2 910 000
Royalton.....	9 687.5508	3.9[illegible]39667 ±	3.24 " " 1 " " 2 990 000
Average.......	10 090		1 part in 2 760 000
Total..........	60 548		

Comparison Between Results for Steel and Invar Tapes.—In order to afford a ready means for comparing the results obtained with the invar and steel tapes, Tables 6 and 7 are given. They show the probable errors of the measures with steel and invar tapes, computed independently.

The results shown in Tables 6 and 7 indicate that the measures with invar tapes are considerably better than those with steel tapes.

If we compare the probable errors obtained before combining with the probable errors due to comparator (as the latter are the same with both kinds of tape), it will be seen that the probable errors from the invar tapes are less than half of those from the steel, if we except the Royalton Base, where the measures with the steel tapes were exceptionally accordant. These probable errors for the measures with steel tapes agree reasonably well with those obtained heretofore, thus showing that a comparison between the measures with invar and steel tapes on these six bases is equivalent to a general comparison between the two metals.

TABLE 6.—PROBABLE ERRORS FOR MEASURES WITH INVAR TAPES.

Base.	Partial.	Due to comparator.	Combined.
	mm.	mm.	mm.
Point Isabel..........	± 2.83	± 1.48	± 3.19 or 1 part in 2 310 000
Willamette..........	± 3.13	± 2.80	± 4.20 " 1 " " 3 340 000
Tacoma.............	± 3.25	± 2.41	± 4.05 " 1 " " 2 980 000
Stephen............	± 4.12	± 1.84	± 4.51 " 1 " " 2 040 000
Brown Valley.......	± 2.06	± 1.64	± 2.64 " 1 " " 3 110 000
Royalton...........	± 3.40	± 1.93	± 3.91 " 1 " " 2 460 000
			Mean, 1 part in 2 630 000

TABLE 7.—PROBABLE ERRORS FOR MEASURES WITH STEEL TAPES.

Base.	Partial.	Due to comparator.	Combined.
	mm.	mm.	mm.
Point Isabel.........	± 5.49	± 1.48	± 5.68 or 1 part in 1 300 000
Willamette..........	± 7.59	± 2.80	± 8.09 " 1 " " 1 730 000
Tacoma.............	± 6.98	± 2.41	± 7.39 " 1 " " 1 630 000
Stephen............	± 7.99	± 1.84	± 8.20 " 1 " " 1 120 000
Brown Valley.......	± 5.55	± 1.64	± 5.79 " 1 " " 1 420 000
Royalton...........	± 3.80	± 1.93	± 4.27 " 1 " " 2 260 000
			Mean, 1 part in 1 500 000

According to these probable errors, the measures with the invar tapes should have a weight of 4 to 1 for measures with steel tapes in combining them for the final length of a base, if only accidental errors are considered; but as there are probably small systematic errors affecting both kinds of tapes, a weight of only 2 to 1 was used in the combination for the final length of a base.

Table 8 shows the actual discrepancy between the lengths of the

six bases as determined with invar and steel tapes, and also the proportional part each discrepancy is of the whole base.

TABLE 8.

Base.	Invar minus steel.	Proportional discrepancy.
	mm.	
Point Isabel	+ 16.5	Or 1 part in 448 000
Willamette	+ 22.0	" " " " 687 000
Tacoma	+ 40.8	" " " " 295 000
Stephen	− 19.3	" " " " 478 000
Brown Valley	+ 00.2	" " " " 41 000 000
Royalton	+ 19.9	" " " " 484 000
Average		1 part in 527 000

These differences are large when compared with the probable errors of the bases, but when compared with other instances where two forms of apparatus have been used on the measurement of a base they are very gratifying. A discrepancy of 1 in 100 000 or more between the lengths of a base obtained with two forms of apparatus is the rule rather than the exception. On the measures of 1900, the duplex apparatus gave results differing from those of the tapes by 1 in 175 000, on an average, which is three times the average discrepancy between the measures with the invar and steel tapes, and nearly twice the greatest difference.

The fact that the sign of the discrepancy between the measures with the invar and steel tapes is the same on all the bases, except one, seems to indicate a constant difference between the two sets of tapes. This one exception is probably due to the fact that part of the measures with steel tapes were made in the rain, thus causing a result sufficiently abnormal to warrant its rejection from this consideration. If the average discrepancy be considered due to errors of temperature, it would require a constant error of 5° on the measures with invar tapes, or 0.17° on the measures with steel tapes, to account for it. The temperature for the invar tapes may be in error a degree, or even a little more, but they are certainly not in error to the extent of 5 degrees. An error of 0.1°, or more, in determining the temperature of the steel tapes, however, either in the standardization or on the measures, or on both, is not only possible, but probable.

Part of these discrepancies may be due to the wind effect on the

tapes. Owing to the twisting of the invar tapes, they present a little of the flat surface to the wind, thus making them more sensitive to breezes than the steel tapes. A careful inspection of the various measures with a view to finding some effect of this character failed to develop anything, as the other errors were large enough to cause these small errors to disappear in the separate sections.

Discussion of Errors.—The results of measurements with tapes and the discussion of their principal errors have been so fully treated in Appendix 8 of the Coast and Geodetic Survey Report for 1892, that it is unnecessary to consider them herein.

The effect of errors due to faulty alignment, both vertically and horizontally, have been eliminated, as previously mentioned, particularly as they are, to some extent, of a compensating character.

The errors caused by faulty tension, although small and partly compensating, are not so completely so as may be desirable. The working balance was usually compared with the two standard balances just before beginning a day's measure and after its completion, particularly if any change were suspected, or if the balance had received unusual handling. It was also frequently suspended by its own hook and its reading noted to see whether the hand had shifted on its pivot, especially after it had received a sudden jerk from any cause.

A change in the working balance of 25 g. (one of the smallest divisions of the dial) was noted occasionally, but no correction was applied to the results for such small errors. They were more or less compensating, and their effect very small. Observations made upon two invar tapes to determine the effect of small changes from the 15-kg. tension gave 0.04 mm. as the effect for a tape length, or 0.8 mm. per km. for a change of 25 g. in tension. The effect upon the steel tapes was considerably less, because they have less mass per unit length and, therefore, less sag under a given tension.

During the work of standardization, the true 15-kg. tension was held very closely, but on the field measures it was impossible to hold it within 25 g. every time. Errors from this source were of the compensating class, however, and their effect on the total length of a base was probably small.

Errors in marking tape lengths are also compensating to a great extent. The graduation mark of the tape was always in the same plane as the copper marking strip on the post, and a tape length was

marked on this copper strip by a line drawn in prolongation of the graduation line. If there were any constant parallax with either observer, it was eliminated in the double measure of the base, as the observers stood on the same side of the posts in all the measures, the two measures always being made in opposite directions.

When preparing the base line, all posts were made solid before leaving them, using braces if necessary to accomplish this purpose. Care was taken to prevent any one from stepping near a post which was holding a measure, hence errors caused by unstable posts were probably negligible, being more or less compensating. No strain was placed on a post, except that necessary to make the mark, which was perpendicular to the base line and not likely to affect the length, especially as the force required was small.

One of the principal sources of error with the steel tapes is the determination of the actual temperature of the tape at the instant of the measure. When the work is progressing rapidly, the tape is moved through the air at a height above the ground two or three times as great as when it is in position for the measure. The time spent in moving from post to post is greater than that necessary to make the measure, hence the tape and thermometers are subject to the temperature of the air at the height of the movement more than at the height of the measure. The temperature near the ground is frequently quite different from that of the air, hence the temperature acquired during the movement is not that of the measure. The tape probably assumes the temperature of its position much more quickly than the thermometers, consequently the thermometers fail to give the actual temperature of the tape at the instant of measure. The fact that the thermometer did not give the temperature of the air in the position of the measure was frequently noticeable when a delay was necessary, as, for example, to measure a set-up. The thermometer would read practically the same while the work was progressing without interruption, but would jump a few tenths of a degree every time a delay occurred, and then return to the original reading as soon as the regular movement was resumed. Errors of this class were more prominent with the steel measures at night than with the invar work in daylight. The temperatures were much more irregular during the day work, of course, but the change during any delay was rarely greater than the usual changes when the work progressed without interruption. In any case,

it was much less than twenty-eight (the ratio of the coefficients of expansion of the two metals) times the temperature differences obtained with the steel tapes.

Cost.—The total cost of the measurement of these six base lines was approximately $7 000, which is at the rate of $116 per km. This includes the cost of standardization, both in the field and at the Bureau of Standards, all expenses of travel and transportation for party and outfit, cost of computations and preparation of results for publication.

If invar tapes only had been used on these measures, the field standardization would have been unnecessary, thereby reducing the cost very materially, probably to less than $100 per km.

The cost of the preparation of the last three bases was $24 per km. The various operations on the other bases were so interwoven that the cost of the different parts cannot be separated.

Advantages of Invar Tapes.—The principal advantages of invar tapes over steel tapes, developed from this season's work, may be summed up as follows:

Invar tapes may be standardized at the Bureau of Standards instead of in the field, thus effecting a very material saving in both time and money.

The measures with invar tapes may be made in daylight instead of at night, as required with steel tapes, thus increasing the speed and accuracy of the work and further reducing the cost. One objection to the use of the tapes at night is that the moisture from the atmosphere condenses upon the tape and thermometer, increasing the weight of the former and causing the latter to give temperatures which are not as accurate as could be desired. Although errors from this latter source were very noticeable on parts of the measures they were never large enough to warrant a re-measure or a delay of the work.

Owing to the very small coefficient of expansion of the invar tapes, the effect of errors in the determination of the temperatures of the tapes is much less for the invar tapes than for the steel tapes, even though the former are used during the day and the latter at night.

The invar tapes require a little more care in their manipulation than the steel tapes, in order not to bend them to a radius of less than about 8 in. They are a little more sensitive to wind effect than the steel tapes, as the flat surface is frequently twisted considerably from the horizontal plane when in use.

As already stated, steel tapes, when used at night and standardized in the field under conditions similar to those obtained on the measure, give results of the same order of accuracy as bar apparatus and with about one-third of the cost. The results obtained on these six base lines show that invar tapes give much more accurate results than steel tapes, and are also more economical. Consequently it may be stated that, if the iced-bar apparatus is excepted, the use of which is too expensive for the measurement of base lines, the invar tape is the most economical and accurate apparatus for the measurement of primary bases.*

* A more detailed account of this work will be published in the Coast and Geodetic Survey Report for 1907, which may be obtained about January 1st, 1908, by those interested, on request to the Superintendent of the Coast and Geodetic Survey, Washington, D. C.

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WATER SUPPLY.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"Is it better policy to purchase and control water-sheds, thereby preventing the pollution of impounding reservoir supplies, or to suffer a certain amount of pollution of such supplies, relying upon filtration to correct the effects thereof?"

BY MESSRS. S. BENT RUSSELL, M. R. SHERRERD AND F. W. BLACKFORD.

S. BENT RUSSELL, M. AM. SOC. C. E.—It is evident from this discussion that the question as to which procedure is the better policy cannot be met with an answer so simple and direct that it will not need much explanation and limitation as to conditions. Mr Russell.

Mr. Fuller has set forth in an admirable way the facts which enter into the problem. He has weighed them in an impartial spirit, and his conclusions, for the most part, seem to be logically drawn. To the speaker, however, it would seem that part of his first conclusion has not been fully demonstrated in his argument. It may yet be shown that, with equal intelligence and watchfulness, the purchase and control plan is equally as efficient as filtration, with regard to the sanitary character of the water. The cases referred to by Mr. Snow will bear this out.

The other part of this conclusion—that in regard to the physical condition of the water—is undoubtedly sound, and is a very strong

* Continued from September, 1907, *Proceedings*.

Mr. Russell. point in favor of filtration. This advantage will usually outweigh the detrimental factor of sentiment against impure water artificially made pure. The truth of this has gained more general credence with the growth of the science of water purification.

To make the involved point more clear, compare two towns, one with a water-shed owned and controlled, the other where a certain amount of pollution is allowed, but filtration is in use. Which has the better water supply? This is still a debatable point among engineers; some favor the former, others as strongly the latter. Either plan will give reasonable safety from water-borne diseases, provided intelligent care is exercised in the management. It might be said, as in the matter of forms of government:

"* * * let fools contest,
That which is best administered is best."

With good administration, the former town will have the better supply, from the point of view of one who thinks a naturally pure water is better than a purified water; while the latter town will be better protected usually against objectionable tastes and odors and visible impurities, as shown by Mr. Fuller. It may be remarked that a majority of water consumers do not inquire into the purity of the supply, if the water is clear and sweet. On one side, therefore, it is found to be a matter of sentiment or prejudice in favor of water naturally free from sewage pollution; on the other, that of prejudice against water which is at times objectionable to the senses. The speaker believes that of late years progress has been in favor of filtration.

If it is admitted that there is no great balance of advantage in favor of either plan as regards quality, the question of cost may then be taken up. At the final test a community usually wants a satisfactory water at the lowest cost. Any further expenditure must be more than justified, in money value, by the superior quality. It must be recognized, as Mr. Clarke says, that the financial question is often a controlling factor. Mr. Fuller shows that, in the matter of cost, filtration has the preference. In any given case, however, the cost will depend upon local conditions, and, therefore, the procedure must be governed by these conditions. Among the local conditions, existing laws and customs, as affecting sanitary control, must be considered.

Mr. Fuller states that there is need for better legislation regarding sanitary matters, and Mr. Snow shows most clearly what proper legislation can do for the protection of water supplies. This brings us to the broad question of proper legislation for controlling the disposal of sewage and wastes, and the pollution of lakes and streams. The speaker understands that, in the matter of such legislation, many of the States, and the United States, as a whole, are sadly behind the best practice of European countries.

These, of course, as far as pertains to the United States, are all questions of the future. Engineers are now working toward the adoption by the Government of wise laws for the protection of future generations against the dangers that will come with increased population, and they should continue in this work with still greater zeal and co-operation. Such laws are required by true public economy in the matters of sanitation and water supply. Proper legislation will reduce to a minimum the expense of protecting the water-sheds. Mr. Russell.

From these considerations, with a view to future public economy and health, the following may be formulated as an answer to the question under discussion: The best policy is to limit the pollution of the water-shed by suitable legislation leading to proper drainage and disposal of wastes, followed, of course, by vigilant enforcement of the laws, so that they will effect their purpose. This should be supplemented by filtration of such character and efficacy as to produce a satisfactory public water supply, as defined by Mr. Fuller.

In the speaker's judgment, the cases requiring purchase of land instead of filtration would be so few that they could be classed as exceptional.

Whether or not this answer is accepted, all may fairly hope for, and work together for, legislation to protect our streams and lakes from pollution, and for the better observance of sanitary laws by the public.

M. R. Sherrerd, M. Am. Soc. C. E.—It seems as if there might be a middle ground between the views expressed in the discussions by Mr. G. W. Fuller and Mr. George A. Soper, one of which points to filtration as the only means of safety, while the other seems to indicate that filtration is not necessary. It seems to the speaker that proper sanitary protection turns on the point of whether water-sheds can be selected which will be safe without filtration; perhaps it will be essential that, in every case, filtration must be resorted to eventually. It would seem possible, where the population is small and perhaps occupies only a portion of the water-shed, that the installation of a sewer system to take off the waste from that population, which represents the more expensive portion of the water-shed (from the standpoint of purchase), could be resorted to, and that the outskirts, which are generally the cheaper part, should be purchased, so that a combination of sanitary measures would be effective for a great many years. This would certainly be a cheaper method in many cities in the United States than the immediate installation of filtration, and would be also a very satisfactory protection for many years. Mr. Sherrerd.

One of the discussions referred to the effect of sedimentation, and it might be of interest to give some figures as to the reduction of bacteria noticed in the water supply designed for a population of some 300 000, where the capacity is about 50 000 000 gal. daily. On this

Mr. Sherrerd. plant there was recently constructed a storage reservoir near the city holding about a month's supply. Formerly, the water was brought down through some 25 miles of pipe line, and, at the intake, the bacteria would run as high as 5 000 per cu. cm., and in the tap water of the city it would be reduced, principally due to the absence of light in the pipe lines and sedimentation in the city reservoirs, to an average of 200 bacteria per cu. cm. After the use of the storage reservoirs, where the water is held for about a month, the bacteria being about the same at the point of intake on the water-shed and the conditions being similar, the number of bacteria in the tap water has been reduced to an average of from 20 to 30 per cu. cm., running along at those figures for months at a time.

There is one other feature in the protection of water supplies which seems to be essential and to which more attention will no doubt be paid in the future; that is, the danger of pollution from railroads traversing the water-sheds. It would seem conclusive, and public health authorities have recommended, that stringent laws will be necessary to secure proper sanitation in this respect unless the railroads see that it is to their interest to provide some sort of sanitary measures. In New Jersey it was proposed that they should go even so far as to enact legislation which would put this matter in the hands of the State Board of Health. This was done at the suggestion of some of the local authorities who were interested in the matter, and at least one railroad has agreed to close the closets on the trains while traversing the water-shed of the Newark water plant. This is done also on the New York, New Haven and Hartford Railroad on the New Haven water-shed, and is being done on the water-shed of the Scranton, Pa., water supply because of an order from the State Board of Health. It was also proposed to do this at Seattle, Wash., on the portion of the road which was to be built through the territory from which that city derives its water supply.

New Jersey has enacted legislation which will allow the cities to provide sewerage facilities for the drainage of the population on water-sheds where the State Board of Health creates a district, and the State Sewer Commission approves the plans. The cities are to pay for the installation of these systems.

To insure that the sewage be treated properly before it is discharged into the stream, it is proposed, on the plan to which reference was made, that a sewer system shall be installed with septic tanks, and that broken-stone sprinkler filters and fine sand filtration shall be resorted to before the outfall discharges into the main stream below the intake. This act provides that, while the city shall pay the entire cost of installation, it may have the authority to enter on private property and cause connections to be made from outhouses or closets to the sewer, and provide proper sanitary arrangements; and it is also pro-

posed that a water supply shall be installed from one of the reservoirs in order that the sewer may be flushed properly. Mr. Sherrerd.

In the speaker's judgment, the purity of the water supply for this particular city will be insured, at least for a great many years. There is one question, however, which is troublesome, namely the fact that by the installation of such a system, particularly in the neighborhood of a suburban section of the metropolitan district around New York, the property, to a certain extent, is made more desirable for residence purposes, particularly for villa sites where people from the metropolis may have all those advantages, so that this has, in a measure, a tendency to increase the population of the district. On the other hand, to attempt to secure by purchase the tracts of land that are necessary to protect a water supply is usually much more expensive than the cost of installing and maintaining adequate sewerage facilities.

The conclusion of the speaker is that conditions must always govern, and that it is essential that the purest water should be obtained primarily; its treatment will depend on circumstances.

F. W. Blackford, M. Am. Soc. C. E.—This question is largely one of economics, and should be considered like any other problem that comes before an engineer. Local conditions make a great difference in such propositions. In populous districts, like those adjoining New York, and in Pennsylvania or New Jersey, and other places similarly situated, it might be impracticable to acquire a water-shed entirely, but in many places it would be practical. Of course, this depends largely on the ability of the community to tax itself sufficiently to obtain a large water-shed or one of sufficient size to furnish a supply, but it is a question of locality and a question of making figures, like other propositions, such as building railroads and adjusting the grades and curves to the amount of money available, and to the traffic which is expected. In many places, even in populous districts where the water supply is drawn from a distant point, a large tract of land could be acquired and controlled absolutely. It does not follow that such land should remain useless; it could be planted in grass or in forest—more properly in forest, which, in the course of a generation, would become profitable; and, while it might also be found necessary to filter the water to some extent, the circumstances might be such that it would not have to be filtered at all. It is an economic proposition, and one should consider the amount which the community under the law could tax itself, the amount of income to be derived, the operating expenses, etc., as against the fixed charges. Mr. Blackford.

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PAVEMENTS.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"Will the paving materials of the present be used in the construction of the pavements of the future?"

BY NELSON P. LEWIS, M. AM. SOC. C. E.

Mr. Lewis. NELSON P. LEWIS, M. AM. SOC. C. E.—This question, as the speaker understands it, is calculated to invite discussion or speculation as to whether or not the popular, successful pavement of the future will be one of those now generally in use, or whether something new will be evolved or developed. Almost every pavement is an evolution. An interesting thought has been brought out concerning another cheap bituminous pavement consisting of asphalt laid on, or mixed with the ground. Here is a reversion to the discovery of the adaptability of asphalt for street pavements or road surfaces. The rock asphalts of Europe being hauled in carts for the purpose of making cistern linings, it was found that material which dropped from the carts, when mixed with the natural road material, formed a smooth, elastic and excellent roadway. This was probably the first asphalt pavement, and observation of the effect of the accidental deposit of asphalt on this road led to the construction of the first European rock asphalt pavement; and, after half a century, we are going back to this accidental type of roadway which brought about the development of the present asphalt pavement. This shows that, after all, bituminous pavements are the result of discovery and chance as well as of evolution.

* Continued from September, 1907, *Proceedings*.

In the speaker's judgment the great trouble with the development of a new paving material is the disposition of the contractor or discoverer to exploit it before he understands it thoroughly. Reference has been made to wood pavements, beginning with the Nicholson block, made of the cheapest material and laid in the most indifferent way. Several cities in the United States had very unfortunate experiences with this pavement, one becoming practically bankrupt through laying large areas of these short-lived blocks. In America this gave wooden pavements a black eye for years. There is now a revival of wooden pavements, and there are evidences of the same disposition to exploit them by laying as many yards as possible at as good a price as can be secured through any influence that may be available. The greater the area laid, the more indifferent seems to be the workmanship, and the less care seems to be given to the selection of material, so that it will occasion little surprise if this material, which is capable of making an admirable pavement, is abused to such an extent that there will be a reaction against it in a very short time. Mr. Lewis.

The adaptability of asphalt has been marvelous; it is found in successful use from Manitoba to the Tropics; in the severe frosts and storms of the North, and in the hot, moist atmosphere of the South. Under the conditions prevailing in the City of Mexico it seems to be admirable, and it is difficult to conceive of a pavement which could be more satisfactory than the asphalt pavements of that city. After all, the real value of a pavement is not determined wholly by its wearing qualities. Its appearance is a most important consideration, and at present there is no material that can be kept so neat and so immaculately clean as asphalt under an efficient system of street cleaning. This is admirably illustrated in the City of Mexico; the speaker cannot recall ever having seen asphalt pavements in better condition, or cleaner, than those laid on the principal streets. In walking to the Mineria, the speaker had a few scraps of paper in his hand, which he tried to dispose of; he had not the temerity, however, to throw them on the streets, which were perfectly clean, so he carried them into the building where he disposed of them. The City Government is to be congratulated upon its ability, not only to lay pavements of this kind well, but to keep them clean and maintain them very thoroughly. The officers in charge of street cleaning in northern cities might profitably visit the City of Mexico for an object lesson.

The selection of the kind of pavement is, after all, what might be called a question of luxury, as has already been said; how good a suit of clothes can a man afford to wear? Imagine the effect, on the rental value of an office building, of a clean pavement from which the dust will not be licked up and blown into the windows by every breath of wind, or of a pavement which is fairly noiseless. If distributed over that rent roll, the money required to renew such a pavement, if

Mr. Lewis. necessary, every three or four years, would be trifling. It is this luxury for which the people of London are willing to pay; the pavement in general use there is not permanent; it has to be renewed every few years, but it is clean and quiet; and the people are willing to submit to the inconvenience of its frequent renewal.

Block pavements are frequently urged and advertised, because they can be repaired so readily; but the argument is fallacious. There is no pavement that can be repaired as readily as modern artificial sheet asphalt pavement. If blocks are removed, they can never be laid as perfectly as they were originally, and when the true surface is gone, the blocks readily deteriorate. There is a disposition to relay the old blocks when they are not badly worn, but, with the sheet asphalt pavement, the material put in is new and has the same life as the original pavement. By the time the pavement is 10 or 15 years old, with the many frequent openings which are unfortunately made, a very large part of it is relatively new. This constant reopening of pavements is annoying and most exasperating, and it is to be hoped that some way will be found to avoid it. As far as the pavements of the future are concerned, the speaker can see nothing to indicate that there will be anything new. As Mr. Tillson has said, almost every material has been tried—glass, straw, iron, wood—almost every elementary substance, and every mixture which ingenuity or imagination can suggest. It is quite probable that the pavement of the future will be quite similar to the pavement of to-day, and the speaker knows of nothing which equals, in its universal adaptability, the modern sheet asphalt pavement.

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FOUNDATIONS.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION.

"(*a*) What is the best system of construction for foundations of heavy structures on ground such as that of the City of Mexico, which is an alluvial deposit about 300 ft. in depth, and similar in character to that at New Orleans?

"(*b*) Will iron or steel used in foundations, independently or in combination with other materials, last indefinitely when in direct or indirect contact with water?

"(*c*) Will the strength and durability of concrete in foundations be affected if before setting there is: (1) an excess of water; (2) lack of compression; (3) too rapid desiccation?"

BY MESSRS. HENRY W. HODGE AND HENRY ROHWER.

HENRY W. HODGE, M. AM. SOC. C. E.—In designing foundations for buildings, there are only three factors to deal with: the loads to be carried, the bearing capacity of the soil, and the friction capacity of the soil. The bearing and friction capacity of the soil can be ascertained by experiment with considerable exactness. It would appear at first that the loads to be carried is the simplest matter to determine, but this is not true, as the moving portion of the load is purely an estimate, and the actual moving loads seldom agree with those assumed. The usual allowance for moving load in an office building is 70 lb. per sq. ft. of floor area, which is taken to be uniform; and in high buildings, the total load does not approximate to an average of this amount on each floor. One of the causes of unequal settlement in foundations of buildings, especially in high buildings where a large total live load has been computed, but which really does not exist, is Mr. Hodge.

* Continued from September, 1907, *Proceedings*.

Mr. Hodge. due to the fact that the foundations are generally computed for a total consisting of live and dead loads.

The columns carrying the outside walls are computed to carry a very heavy dead load, which is sure; and a comparatively small live load, which is doubtful; whereas, the interior columns are computed to carry a relatively light dead load and a much heavier live load, as the live load can come from all sides to these columns. Consequently, the actual unit pressure under the wall columns is extremely likely to exceed the actual unit pressure under the interior columns, and therefore they settle unequally.

While the speaker agrees with Señor Marroquin that under uniform loads the periphery settles more slowly than the interior, yet, in view of the fact that, for the foregoing reasons, the actual pressure at the periphery is generally greater than the interior pressure, it often occurs that the exterior columns of a building settle more than the interior, and the speaker has seen several buildings in which the outer walls had settled so much more than the interior that the floors had a decided dip from the center in all directions to the walls. It is the speaker's opinion that it would be better engineering practice to calculate all foundation pressures for dead loads only, and set unit pressures at such a low value that they could stand safely the additional weight due to such moving loads as might come upon the building. The speaker is not at all a believer in the practice of building one continuous platform or "raft" as a foundation for a building on compressible soils, as it is impossible to distribute the total load of the building uniformly over such a platform, and the consequence of unequal pressures is that these platforms will break and cause cracks, and in buildings on a street corner where two of the exterior walls are of stone, and of considerable thickness in order to give the necessary architectural appearance, whereas the remaining two walls are of skeleton construction, the increased weight on one side of the platform foundation is often such as to tip the whole foundation and throw the building out of plumb, as has been done in the case of some tall buildings in New York City.

In the speaker's opinion, the best form of foundation on yielding soils is a series of small platforms, each independent of the other, and each proportioned for the load coming directly upon it, so as to make the foundation pressure under all platforms uniform, and, if such a form of foundation is followed, it is not a matter of great importance if settlement does occur, provided the building has been started high enough to allow for this settlement, as there are many buildings now in perfectly good condition which have settled as much as 2 or 3 ft. without showing any serious damage. Of course, on a soil as compressible as that under the City of Mexico, it would be impossible to get area enough under tall buildings to support the building on a series of platforms, and in such a case some form of frictional pile

must be used, and it would appear to the speaker that the sand piles which have been mentioned would fill the conditions excellently. Evidently, there are interstices in the underlying strata which must be filled up, and these sand piles seem to fill in these interstices effectually. It might even be found possible to fill the interstices with cement grout as was done by A. P. Boller, M. Am. Soc. C. E., when he solidified the rip-rap filling under some bridge piers for the New York and Northern Railway, by forcing iron pipes into this rip-rap and pumping cement grout through it until it filled completely all the interstices of the rip-rap, and formed one solid monolith. Mr. Hodge.

Henry Rohwer, M. Am. Soc. C. E. (by letter).—It is found invariably that water is the principal factor in making soil instable, so that careful preparation is required in order to carry structures of great height. In Louisiana, and also in the City of Mexico, the soil is so permeable that water enters and mixes with it, thus making it loose and slushy. By compressing the ground, or condensing its volume, the water is driven out, and the soil is made capable of greater resistance. Mr. Rohwer.

It is also necessary to drain the soil, but the extent to which this can be done depends on the geological and topographical formation of the surrounding country. If the ground is level, and no underground drainage can be established at reasonable cost or within the limits of practicability, the writer recommends the following proceedings:

First, compress the soil by driving piles after the excavation has been made to conform to the bottom of the basement level, and then construct a flooring capable of receiving and distributing the weight of the building.

Second, collect the water in sumps or wells, and arrange the construction of the floor and foundation in such a way that the weight of the walls will assist in the retention of the ground level within, and *vice versa,* thus preventing the tendency to upheaval in the middle by the pressure of the walls, or the soil and water on the outside which has not been excavated to the same level. This may be done by a flooring of reinforced concrete strong enough to resist the pressure expected, and tied to the walls so that it may be considered as practically a portion thereof, thus making the weight on the walls help the floor to maintain equilibrium.

In both cases the whole area inside the building lines will act as one bearing surface, and the walls with a spread footing will help to make it effective. The first, and cheaper, method may be rendered as effective as the second, if constructed properly.

In applying "pressure piling" the writer has met with marked success, and has compressed ground bearing not more than 250 lb. per sq. ft. so that it would bear more than 3 000 lb. per sq. ft. Some of this work, done in 1888, is still in perfect condition.

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COMPARISON OF RAINFALL AND RUN-OFF IN THE NORTHEASTERN UNITED STATES.

Discussion.*

BY MESSRS. RAPHAEL ZON, C. C. VERMEULE AND H. K. BARROWS.

Mr. Zon. RAPHAEL ZON, ESQ.† (by letter).—The data on the relation between precipitation and run-off brought together by Mr. Hoyt are of great scientific and practical importance. Unfortunately, the figures apply to large drainage areas. As a rule, these present a complex of conditions which often compensate and counteract each other, and, therefore, obscure the real factors affecting the run-off. In many cases large drainage areas, radically different from each other, yielded practically the same final results, from which general conclusions were often made, which could not be corroborated by observations on smaller water-sheds.

The figures of precipitation and run-off over large drainage areas, each presenting varied conditions, cannot give proper consideration to all factors affecting run-off. Such observations naturally bring out only the general factors, such as precipitation and temperature. Thus Professor A. Penk, one of the best authorities upon the regime of the Elbe, Danube, and other rivers of Middle Europe, by observing the large drainage basins of these streams, came to the conclusion that the annual discharge of rivers depends only upon temperature and precipitation; and that the ratio of the run-off to precipitation on water-sheds of radically different character remains the same, namely, the run-off constitutes about seven-tenths of the precipitation above a certain minimum (420 mm.). If the precipitation were to fall below this minimum, there would be no run-off.

* Continued from September, 1907, *Proceedings*.

† Chief, Branch of Silviculture, Forest Service, U. S. Dept. of Agriculture.

Mr. Newell found about the same ratio for the drainage basins of North American rivers. According to Mr. Newell, the minimum precipitation, above which run-off takes place, is 300 mm., and the run-off is equal to eight-tenths of the precipitation above this minimum. Investigations on small catchment areas show that the relationship between precipitation and temperature, on one hand, and run-off, on the other, is not so simple. On small water-sheds where the different conditions may be accounted for, the effect of other factors is much plainer than on large drainage basins, and therefore they are apt to yield more reliable results. Mr. Zon.

Besides precipitation and temperature, the vegetative cover of the water-sheds, especially the forest cover, affects the quantity and the character of the run-off. It is a well-established fact that the quantity of water available for stream flow from forested water-sheds, all other conditions being equal, is less than from non-forested water-sheds, and it is clear why it must be so. The amount of precipitation which reaches the soil in the forest is always less than that which reaches the soil in the open, because of the interception of a part of the water by the crowns of the trees. The quantity of soil in the forest varies with the species and age of the trees, and the development of the crowns and the kind of foliage. Light rains are almost totally intercepted by the crowns without reaching the soil; the heavier the rains, the more water reaches the forest soil. The amount of precipitation which is lost in this way for the forest soil is greater in coniferous than in broad-leaved forests. It is equal to 20% of all the precipitation in a hard-wood forest; in a thin coniferous forest it is 30%, and, in a dense spruce forest, it is from 30 to 45 per cent. For this reason, coniferous forests, although they transpire less water than broad-leaved forests, demand a climate with heavier precipitation, mountain slopes, for instance, or soils with a greater water-carrying capacity, preferably sands.

Besides the interception of precipitation by the crowns of trees, a loss of moisture on the way to the soil is also occasioned by the forest litter, which absorbs part of the water reaching the forest floor. According to Wollny's experiments, a layer of litter 5 cm. deep, composed of leaves and needles, and exposed to sun and light, allows only from 64 to 70% of all the precipitation that falls upon the forest floor to reach the soil, and only 53% reaches the soil through a layer of moss of the same depth. Thus the forest soil receives the least precipitation, next comes meadow land, and lastly tilled land.

In the forest, only the upper layer of the soil is moister than in the open, the lower layers being always drier. Thus, according to Ebermayer's experiments of 1884-86, the percentage of soil humidity at different depths in an uneven, aged, spruce forest and in the adjoining field is as shown in Table 7.

Mr. Zon.

TABLE 7.

Depth.	Young forest, 25 years old. Percentage.	Middle-aged forest, 60 years old. Percentage.	Mature forest, 120 years old. Percentage.	Field. Percentage.
0- 5 cm........	28.97	20.48	40.25	22.33
15-20 "	19.19	19.07	19.29	20.62
30-35 "	19.10	16.07	18.29	20.54
45-50 "	18.39	16.26	20.22	20.24
75-80 "	18.00	17.90	21.12	20.53
Average....	16.67	17.82	19.73	20.23

The middle-aged forest always produces the greatest desiccation of the lower layers of the soil. This is especially noticeable in summer and fall. In such a forest the soil humidity at a depth of 40 cm. is, on an average for the summer, 15.12%, while in the field at the same depth it is 19.89 per cent. The dryness of the soil under the forest is caused by the transpiration of water by the forest. Since trees produce more organic substance per unit of area than other plants, their expenditure of water for the formation of cells, therefore, must also be greater. The enormous transpiration of water by the forest and the smaller amount of precipitation received by the forest soil cause the greater dryness of the soil under the forest.

All this goes to show that the forest cover tends to decrease the total quantity of water available for stream flow. A comparison of forested and non-forested water-sheds, especially in the South, would probably show a smaller total amount of run-off from forested, than from non-forested, water-sheds. It would also show, however, a difference in the distribution of the run-off throughout the year, and throughout a cycle of dry and wet seasons. In all cases, the forest tends to decrease the difference between the maximum and minimum run-off, and to maintain a steady flow of streams. This is very clearly shown by Professor Toumey's investigation in the San Bernardino Mountains of Southern California. Here the run-off during the dry summer months was maintained in the forested areas, while, over an unforested area, under the same conditions, there was practically no run-off during the summer. The data concerning precipitation and run-off, as brought out by Mr. Hoyt, while true for average conditions, such as exist over large drainage basins, may not be applicable to smaller streams and water-sheds where there is a lesser variety of conditions which compensate each other, and, therefore, other factors, besides precipitation, are at play.

Mr. Vermeule. C. C. VERMEULE, ESQ. (by letter).—While there has been accumulated a large addition to the records of stream measurements in the United States during the past ten years, the writer has not yet found it possible to ignore the effect of differences of rainfall, temperature,

cultivation and soil conditions in computing the run-off of any stream for which gaugings do not exist and for which he finds it necessary to have the most accurate estimate of run-off which can be made. Mr. Vermeule.

The differences in run-off of streams in the same region are so great that to apply directly the gaugings of one stream to some other stream, without correction, must be regarded as unscientific and unsatisfactory. If we have not at hand accurate measurements of precipitation upon the two streams covering a considerable number of years, we may be unable to do better, but with measurements of precipitation and of temperature, and an examination of the respective water-sheds, carefully noting differences in soil conditions, topography, forestation and cultivation, the hydraulic engineer of experience should be able to make a much closer approximation to the run-off by properly correcting a set of gaugings to allow for these differences. Such correction can only be made after one has familiarized himself with the phenomena and the laws which govern the relation between rainfall, temperature, topography, soil conditions, and the run-off of streams. A patient and careful analysis of such data has brought the writer to the firm conviction that the greatest need is that certain typical streams throughout the United States, comparatively limited in number, should be gauged with a high degree of accuracy, with simultaneous rainfall measurements at a number of well-selected points upon their water-sheds, and that these gaugings should be continued over a considerable period. The same money expended in gauging a very large number of streams in an indifferent manner, without careful simultaneous rainfall records, if expended upon more careful measurements of one-tenth of the number of streams selected as typical water-sheds would do far more to reduce hydrology to a science.

In studying the relation between rainfall and run-off, it is necessary to keep in mind the fact that the run-off is merely the difference between the rainfall and the evaporation taken in its broad sense to include the water taken up by vegetation as well as that directly evaporated in the atmosphere. Under ordinary natural conditions, the water which percolates downward and does not reappear through springs is insignificant in amount. Evaporation obeys well-known laws which have been the subject of much study and investigation, so that there is much at hand on which to base a reasonable method of computing it. It is to a large extent a function of the temperature. Having the rainfall for a given period, if the evaporation for the same period could be computed, the difference should represent the run-off, and it will be found to do so, nearly, if the period in question begins and ends with the free ground-water at substantially the same level. In actual experience, however, it will be found that, with the same amount of rainfall, the run-off may vary in different years from about 37% to about 63% of the rainfall, or as much as 10 in. per

Mr. Vermeule. annum. Under such conditions, the scientific mind cannot be satisfied to proceed with any rule-of-thumb method, or with any method which does not allow for such variations. This particular difference is due to the water taken up by the ground and stored therein, to be fed out to the streams later during the dry season, and it illustrates the very important effect of soil and sub-soil conditions in maintaining the dry-season flow and equalizing the yield of the stream.

About 1890 it became the writer's duty to make as accurate an estimate as possible of the run-off of the streams of the State of New Jersey. This, at that time, had become urgently necessary, and there was no time for extended gaugings of streams. Gaugings were made to a very considerable extent during the four years of work, but much reliance had to be placed upon the longer series of measurements then available upon the Sudbury, Connecticut, Croton, Tohickon, Neshaminy and Perkiomen. Through the courtesy of the Dundee Water Power and Land Company, the writer was also fortunate enough to obtain a 17-year record upon the Passaic. A study of these records showed a marked resemblance between the Sudbury, Croton and Passaic, so striking on close analysis that it was found that these three streams exhibited a quite well-defined relationship between rainfall and run-off. After plotting the results, a formula was deduced to cover this relation, but it soon became evident that the data exhibited by these measurements could not be used as applicable to other streams in New Jersey without correction. This led to the application of a correction, due to differences of evaporation, which was found to increase and decrease with the temperature, and a further correction which followed for differences in topography and soil conditions, or, in other words, the varying effect of ground storage.

Later, in 1899, while investigating the effect of forests upon stream flow, the writer utilized additional data then available covering thirty-four streams in the Eastern United States, extending from the Merrimac on the north to the Savannah on the south, together with a few in the Mississippi Valley and four in England. Giving these results weight in accordance with the length of the record and the known reliability of the rainfall and run-off measurements, a more accurate formula for computing the evaporation from the rainfall was deduced.* The results given by this formula agreed with the observed results upon seventeen streams having an average length of record of 12 years, in all cases within 5%, the mean error being only 1½ per cent. Three more streams, with records averaging 11 years, vary from 6 to 8%, and the remaining fourteen streams, having shorter records, averaging 6.5 years, show wider differences, the average discrepancy being 5 per cent. These results, together with later experiences, have convinced the writer that it is possible to evolve a formula and method of computing run-off from rainfall which, generally speaking, will

* Geological Survey of New Jersey, Annual Report for 1899, p. 149.

give results far more reliable than can be obtained either from adopting figures of run-off on other streams without correction, or from gaugings upon the stream in question if they do not extend over a longer period than 5 or 6 years. One has only to examine any reliable record, such as that of the Sudbury, in order to be warned that gaugings which extend over only one or two years may vary so widely from average experience upon any given stream as to be not an aid, but possibly a hindrance, to good judgment. Short series of gaugings may be very valuable, if used properly, that is, by taking into account the rainfall during the period together with the average rainfall, and the rainfall for the driest years upon the same water-shed. Here, again, one must know with reasonable accuracy the true relation between rainfall and run-off. Mr. Vermeule.

Personally, the writer has never found much use for percentages in the computation of run-off. If percentages are determined from average rainfall and run-off, they are only applicable to a fictitious average year, or a year which never actually occurs in Nature. Examine any extended run-off measurements, and it will be readily discovered that, during many months in which little or no rainfall occurs, the stream will continue to discharge a considerable quantity of water. This makes it evident that there is no direct relation whatever between the run-off in any given month and the rainfall for that month. This does not refer to winter when the precipitation is locked up in snow, but to the dry hot months in summer. For water-power purposes the writer has of late been able to obtain excellent results by taking gaugings covering a long period upon a stream on which the topography and soil conditions are similar to the one for which he is estimating, and determining by actual count the number of days during which this stream stood at or above given stages of flow, and then plotting the results in a diagram. Having done this, he determines as accurately as possible, from the records of the United States Weather Bureau, the average rainfall and temperature upon this stream during the period covered by the gaugings, and then determines the same data for the stream to be estimated; next, he computes the evaporation and run-off for each stream, and increases or decreases the stages of flow in the proportion that the run-off upon the measured stream bears to the run-off of the stream to be estimated, plotting a corrected curve for the stream to be estimated. Where this method has been adopted and afterward compared with the records of water-power owners upon the stream, a close agreement between the two has been found.

The accurate computation of run-off is useful mainly to determine the amount of storage needed to maintain a given yield, or the amount of water-power to be obtained upon a given stream. To some the whole subject may seem to be largely academic, but, not only is it of importance for the purposes indicated, but the relation between rainfall and run-off is of general scientific interest, and bears upon the

Mr. Vermeule. subjects of forestry, sub-soil drainage, irrigation, etc. While it is a study which requires more time and closer application than can usually be given to it by an engineer in active practice, this is the best reason why we should the more readily encourage every attempt to elucidate the subject and to simplify and improve the resulting formulas and conclusions.

The time when there will be at hand reliable and adequate gaugings of each stream one is called upon to develop is still far distant. Meanwhile, there is need to know how to compute scientifically from the meteorological data now so generally available.

Mr. Barrows. H. K. BARROWS, ASSOC. M. AM. SOC. C. E.—The speaker wishes to comment briefly on several points in Mr. Hoyt's interesting and instructive paper, especially on the matter of accuracy of methods in use by the United States Geological Survey.

The Geological Survey has given much attention to the accuracy of both field and office work in stream gauging, and every effort, consistent with the general object of this work, has been made to obtain data relating to or confirming its accuracy. Some of this information has appeared in the Water Supply Papers, already published, while many additional unpublished data have been obtained by the various district hydrographers.

Previous to 1906 the progress reports of stream measurements contained no comments regarding the accuracy of estimates of flow. In the report for 1906, however, an attempt has been made to ascribe to each gauging station an accuracy factor—in many cases varying with the time of the year. The general remarks relating to this factor are:*

"In order to give engineers an idea of the relative value of the various data, notes in regard to accuracy are given as far as possible. This accuracy depends on the general local conditions at the gaging stations and the amount of data collected. Every effort possible is made to so locate the stations that the data collected will give a high degree of accuracy. This is not always possible, but it is considered better to publish rough values with explanatory notes rather than no data.

"In the accuracy notes the following terms have been used, indicating the probable accuracy in per cent. of the mean monthly flow. As these values are mean values, the error in the value for the flow of any individual day may be much larger.

"Excellent indicates that the mean monthly flow is probably accurate to within 5 per cent.; good, to within 10 per cent.; fair, to within 15 per cent.; approximate, to within 25 per cent."

Mr. Merriman especially criticises the current-meter gaugings of flow and the results obtained with the small Price current meter, but agrees that the unbalanced errors of gauge-height observation in monthly mean discharge will be small. In the speaker's opinion, the current-meter gaugings—and therefore the discharge-rating curves—

* Water Supply and Irrigation Paper No. 201, p. 12.

constitute the most reliable part of these data. Mr. Hoyt has shown one example of these rating curves, from the great number that exist, and it is quite unnecessary to call further attention to the remarkable consistency of the current-meter measurements in their relation to the discharge-rating curve. Mr. Barrows.

What the absolute errors are can only be determined by comparison with some other standard of measurement—sharp-crested weirs, measuring tanks, etc.—but, thus far, such comparisons as have been made indicate that a carefully made current-meter measurement at the ordinary gauging station will give results far within the degree of accuracy required in such work.

At one of the gauging stations of the Geological Survey, *viz.*, Little River, at Blandford, Mass., it has been possible during a portion of the past year to maintain a sharp-crested weir just below the regular station, thus enabling a direct comparison of results by these two methods of measurement. These are given in detail in Water Supply Paper No. 201, pp. 105-110, but a summary of results by months will be of interest, and is given in Table 8.

TABLE 8.—MONTHLY MEAN DISCHARGE OF WESTFIELD LITTLE RIVER, NEAR BLANDFORD, MASS., 1906, AS DETERMINED BY WEIR AND CURRENT-METER RATINGS.

Month.	Discharge in Cubic Feet per Second by		Percentage of difference as regards discharge by weir.
	Weir.	Current meter.	
August (10-31)	12.3	13.0	+5.7
September	9.1	9.0	−0.9
October	42.2	42.9	+1.7
November	55.7	57.6	+1.6
Average for period			+2.0

While the daily discharge by these two methods exhibits a considerable percentage of variation at times, the monthly means, and even the weekly means, are remarkably close in agreement. Furthermore, this gauging station is what would be classed as only a fair station—the stream bed being very rough. The differences in this case are evidently mostly due to errors or inaccuracies in gauge readings. It will be noticed, further, that the differences at some times are positive, at other times negative.

Mr. Hoyt's paper deals solely with large drainage areas where the average rainfall is fairly well determined. Information is frequently needed about rainfall and run-off from small drainage areas—perhaps from 10 to 50 sq. miles—such as frequently have to be considered in

Mr. Barrows.

TABLE 9.

	Run-off, in Inches, on Drainage Area, for the Period Given.													Rainfall for the year, in inches.	Percentage of run-off for the year.	Total loss for the year, in inches.
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	The Year.			
Kennebec River, at Waterville, Maine, 1893–1905, inclusive, 4 270 sq. miles...	0.77	0.77	2.34	5.90	4.96	2.44	1.88	1.04	0.78	0.80	1.09	0.93	23.70	39.63	0.60	15.93
Cobbosseecontee Stream, at Gardiner, Maine, 1891-1905, inclusive, 240 sq. miles ...	1.13	1.11	3.19	3.03	1.81	1.20	1.08	1.13	1.00	0.91	0.83	0.97	17.39	42.18	0.41	24.79

procuring a municipal water supply. In such cases the storage area of tributary ground-water may depart considerably from the topographic limits of the drainage basin and markedly affect the low-water flow per square mile. Local areas of high average rainfall may be included—this being especially common upon mountain slopes—so that the run-off per square mile will be much higher than with small drainage areas under ordinary conditions. This last condition is well illustrated by the run-off of small drainage basins in the White Mountain region, New Hampshire,* noticeably that of Israel, Ammonoosuc and Zealand Rivers. Mr. Barrows.

The storage of water by lakes or reservoirs in the drainage basin, if of considerable amount, will modify the run-off in monthly distribution, and may also in the total amount for the year on account of evaporation of the water while being held.

Table 9 shows the rainfall and run-off data relating to the Kennebec River and Cobbosseecontee Stream, Maine.†

The Kennebec River, at Waterville, has a lake surface of about 5% of the total drainage area at that point, and, of this amount, only a little more than one-half is utilized for storage purposes.

Cobbosseecontee Stream has about 9% lake surface, nearly all of which is utilized for storage. While the total run-off for the year is less for Cobbosseecontee Stream, as indicated in Table 9, yet the monthly means do not fluctuate as much, and the unit flow during the low-water season is always greater.

* Water Supply Papers Nos. 97, 124, 165 and 201; also reports of the New Hampshire State Forestry Commission, 1903-06.

† Water Supply Paper No. 198.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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REINFORCED CONCRETE PIPE FOR CARRYING WATER UNDER PRESSURE.

Discussion.*

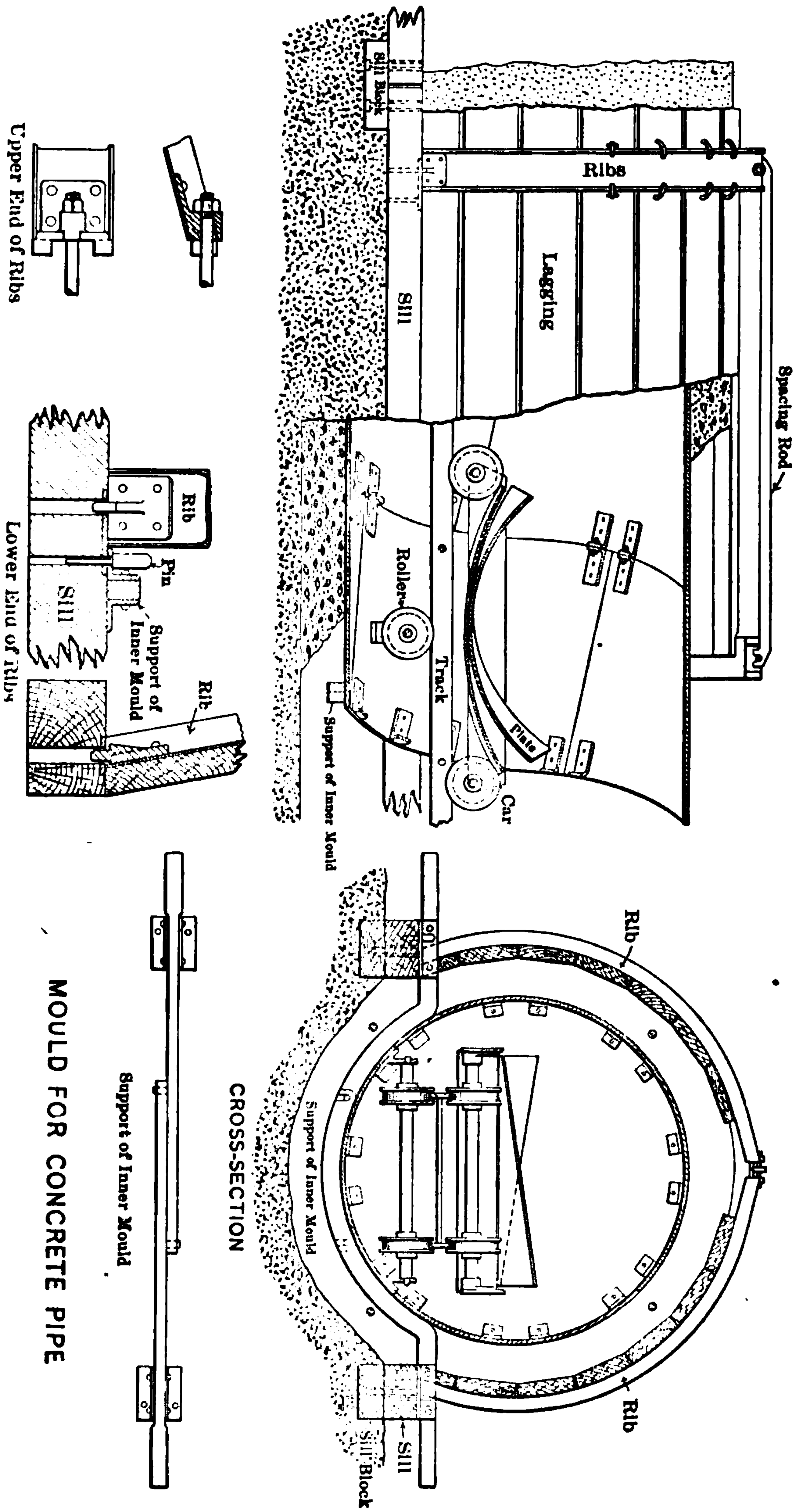
BY MESSRS. F. TEICHMAN AND J. R. WORCESTER.

Mr. Teichman. F. TEICHMAN, M. AM. SOC. C. E. (by letter).—To make good concrete pipe, and to make it at a low cost, three things are required: experience, care, and a good apparatus for moulding the pipe. As to the mould used in building the concrete pipes of the Salt River Project, it gave satisfactory results, on the whole, but by close observation of the apparatus in the field, and of the pipe made by the apparatus, the writer (who designed the mould) arrived at the following conclusions:

1.—For a pipe large enough in diameter to allow a man to do the dismantling of the inner mould, no parts of this mould should be pulled along on the inner face of the pipe (as was the alligator). In preference, the dismantled parts of the rear should be forwarded to the front, and should be erected rigidly there. The three reasons against a sliding mould are: The continuous or intermittent pulling ahead of the inner mould or parts thereof (the alligator) is likely to disturb the support of the concrete while setting, thus establishing a weakness in the concrete, or a defective union between the reinforcement and the concrete. Parts of the concrete while setting may adhere to the moving mould, thus making a face that is marred, defective in appearance, and in compactness and density of concrete. The movement of the mould is not under easy control as to alignment, and it is impossible to make, at will, angles in the alignment of the pipe without interrupting the continuity of the work.

* This discussion (of the paper by Chester Wason Smith, Assoc. M. Am. Soc. C. E., printed in *Proceedings* for August, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Teichman.



MOULD FOR CONCRETE PIPE

FIG. 5.

Mr. Teichman. 2.—The ribs for the lagging of the outer mould should not be suspended from a framework, but should be supported preferably on sills resting on the ground. The support on sills gives greater rigidity to the outer mould than the suspension from a framework.

3.—The wheeling planks should not be supported by the same structure which supports the mould, otherwise the jars occasioned by the loaded wheel-barrows or cars may be felt in the mould, and this may injure the concrete work.

4.—The inner and outer moulds should be erected on the same base —sills laid on the ground—thus assuring their concentricity. Concentricity makes possible the reduction of the thickness of the pipe to a minimum, and a pipe is cheaper and better, the thinner its walls are, provided the reinforcement is properly embedded and the concrete of the wall is strong enough as a beam to support the inner pressure between two adjoining reinforcement rings.

5.—Inside the inner mould there should be a track with a car, to carry to the forward end of the mould the plates dismantled at the rear. This track should rest on rollers, placed at intervals near the bottom of the inner mould. A track, thus supported, can be pushed ahead at will so as to be always in a convenient position, for both the rear and front plate men.

6.—Instead of arranging the plates of the inner mould in individual courses, square to the axis of the pipe, it is preferable to arrange them in a continuous spiral, in such a manner that their joints, which are square to the spiral, will always be staggered, *i. e.*, strike the plates of the adjoining spiral courses in their middle. For pipe of ordinary diameters, this will give stiffness to the inner mould, even without the use of stiffening angle iron, or brace rods. The spiral plates for a cylindrical pipe mould are as easily made as those for individual courses, but are more easily dismantled and erected than the latter.

7.—The ribs of the outer mould should be arranged so that the two halves of one rib may be spread more or less at the top as well as at the bottom (with the sills), in order to permit some variation in the thickness of the concrete. The rib halves must be removable before any lagging inside the ribs is removed.

On the basis of these principles, the writer has designed a mould for ordinary pipes of small diameter, as illustrated in Fig. 5. The supports for the inner mould, of course, are in use only ahead of the concrete work, and as the concrete approaches them, they are withdrawn (by first spreading the two halves) and moved to the front. While in use, these supports are pinned to the sills, just as the ribs of the outer mould are. This secures concentricity of both moulds. Any slight change in the direction of the pipe is made by leaving open the spiral joints of the inner mould at one side and covering the gap with light iron or tar-paper. At such changes of direction, special

sills and lagging, cut to special lengths, are required for the outer mould. Mr. Teichman

The inner track will accommodate itself to slight lateral changes by connecting the different lengths of track by bolts in slotted holes.

The radial dimension of the supports of the inner mould is small enough so that these supports are always inside the longitudinal reinforcing rods, and the length of the arch of these supports is such that the supports may be withdrawn without interfering with these reinforcing rods, if they are spaced in the usual manner.

J. R. Worcester, M. Am. Soc. C. E. (by letter).—The author's experience with these pressure pipes is particularly interesting, in the light it sheds upon the question of the amount of longitudinal reinforcement necessary to prevent transverse cracks in long straight structures. Mr. Worcester

It has been held by some authorities that longitudinal steel to the amount of half of 1% of the area of the concrete is necessary, and it is generally conceded that the proportion is wholly efficient. In underground pipes and tunnels, many have ventured to use considerably less than this, but the determination of the precise quantity has not yet been made, and, in the mean time, all light shed upon the subject is very valuable.

It seems that in the case of the Pinto pipe, the proportion of longitudinal steel to concrete in the portion of the section with cylindrical exterior was about 0.0014. That in one of the pipes of this line there should have been 40 transverse cracks in 2 400 ft., or one to each 60 ft., would not seem surprising, considering the low percentage of steel; and it would seem to be due to an unusual combination of favoring conditions that the other line showed so few.

In the Cottonwood lines, where the ratio of steel to concrete was about 0.002, it would be interesting to know how much of the immunity from cracks was due to the conditions under which the pipes were laid, and how much to the greater percentage of steel.

PROCEEDINGS

OF THE

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OF

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SOCIETY AFFAIRS.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

October 16th, 1907.—The meeting was called to order at 8.30 P. M.; Director George W. Tillson in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 213 members and 69 guests.

A paper by J. C. Meem, M. Am. Soc. C. E., entitled "The Bracing of Trenches and Tunnels, with Practical Formulas for Earth Pressures," was presented by the author, and illustrated with lantern slides. Written discussions from Messrs. Horace J. Howe, C. W. Birch-Nord, Lazarus White and E. G. Haines were presented by the Assistant Secretary, and the paper was discussed orally by Messrs. F. T. Llewellyn, H. P. Moran, John F. O'Rourke, V. H. Hewes, T. Kennard Thomson, E. P. Goodrich, O. F. Nichols, E. W. Stern, G. L. Christian, W. H. Gahagan, R. A. Shailer, H. B. Seaman and the author.

Adjourned.

November 6th, 1907.—The meeting was called to order at 8.30 P. M.; Director A. L. Bowman in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 72 members and 14 guests.

A paper entitled "Water Purification at St. Louis, Mo.," by Edward E. Wall, M. Am. Soc. C. E., was presented by the Assistant Secretary, who also read communications on the subject from Messrs. Philip Burgess and Edward Prince. The paper was discussed orally by Messrs. G. A. Soper, G. C. Whipple and L. L. Tribus.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Alexander Mosby Clayton Byers, City of Mexico, Mexico.
Thomas Wiley Clayton, Shawneetown, Ill.
George Russell Field, San Francisco, Cal.
Frederick Charles Herrmann, Calexico, Cal.
Charles Hanford Kendall, Manila, Philippine Islands.
George Arnold McCarthy, North Bay, Ont., Canada.
Hood McKay, Lansford, Pa.
Jacob Bomberger Rohrer, San Francisco, Cal.
Howard Everett Smith, Albany, N. Y.

As Associate Members.

Frederick William Altstaetter, Pittsburg, Pa.
Emanuel Anderson, City of Mexico, Mexico.
Frederic Herbert Bass, Minneapolis, Minn.
William Bernard Bates, Roanoke, Va.
Philip Asfordby Beatty, Baltimore, Md.
Edward Crosby Bebb, Glendive, Mont.
Maurice Otto Bellingrodt, Atlanta, Ga.
Will Hazen Boughton, Morgantown, W. Va.
Charles Bradshaw, San Bernardino, Cal.
Leonard Dempster Brownell, Syracuse, N. Y.
Robert George Dieck, Portland, Ore.
Samuel Douglass Dodge, Cornwall-on-Hudson, N. Y.
Edward Bowman Espenshade, Roundup, Mont.
Wager Fisher, Philadelphia, Pa.
Percival Morris Fogg, Newlon, Mont.
Philip Guise, Brooklyn, N. Y.
William Cary Hattan, Altapass, N. C.
Guy Frederic Hosmer, Old Town, Me.
Frederick Milton Hough, Saratoga, Wyo.

Anders Jordahl, New York City.
George Israel Oakley, Little Falls, N. Y.
Joseph William Obreiter, Jersey City, N. J.
Henry Garfield Perring, Philadelphia, Pa.
Edward Hawks Ravenscroft, Chicago, Ill.
Warren Fuller Rugg, Peekskill, N. Y.
George M. Stevens, Boston, Mass.
Thomas Patton Stevenson, Rio de Janeiro, Brazil.
Garfield Stubblefield, Hermiston, Ore.
Harry Edward Wagner, Providence, R. I.
Ralph Whitman, Washington, D. C.
Harry Blakemore Wrigley, Philadelphia, Pa.

As Associates.

Robert Anderson, Cincinnati, Ohio.
Henry McBurney, Stockbridge, Mass.
Davis Harrington Morris, Dayton, Ohio.

The Secretary announced:

The transfer of the following candidates by the Board of Direction on November 5th, 1907:

From Associate Member to Member.

Charles Rufus Harte, New Haven, Conn.
James Vincent Rockwell, Mare Island, Cal.
Robert Swan Sumner, Denver, Colo.
Edward Moses Stayton, Independence, Mo.
Guy Bennett Waite, New York City.

The election of the following candidates by the Board of Direction:

As Juniors.

On June 4th, 1907:

Guy Alfred Hersey, Medford Center, Me.

On September 3d, 1907:

Norman Marshall Halcombe, Stanford University, Cal.

On October 1st, 1907:

Arthur Wellesley Coombs, Brooklyn, N. Y.
Reginald Truman Hurdle, Tokna, Mont.

On November 5th, 1907:

FREDERICK LUCIUS COPELAND, Janesville, Wis.
EDWIN LEROY DRIGGS, Lujane, Colo.
THOMAS FLEMING, JR., Pittsburg, Pa.
HEBER GOSSLER GEARHART, Duquesne, Pa.
EVERETT HAMILTON HATCH, Vallecito, Cal.
CHESTER BROOKS LEWIS, Indianapolis, Ind.
HALLET RICE ROBBINS, Albany, N. Y.
SIDNEY DAVIS STRONG, Sault Ste. Marie, Mich.
JOHN RUSSELL VAN HORNE, New York City.
JOHN LEONARD VOGEL, Jersey City, N. J.
GEORGE MERRITT WARD, Hatfield, Wis.
HARRY PERCIVAL WILSON, Boston, Mass.

The Secretary announced the following deaths:

JOHN HOWARD CLARK, elected Member, November 4th, 1903; died October 13th, 1907.

CHARLES EZRA HEQUEMBOURG, elected Member, June 5th, 1901; died October 17th, 1907.

JONATHAN WAINWRIGHT, elected Member, February 3d, 1892; died October 11th, 1907.

Adjourned.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, December 4th, 1907.—8.30 P. M.—Ballots for membership will be canvassed, and a paper entitled "Invar (Nickel-Steel) Tapes on the Measurement of Six Primary Base Lines," by Owen B. French, M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for October, 1907.

Wednesday, December 18th, 1907.—8.30 P. M.—A paper entitled "Municipal Sewage Disposal—An Investigation," by J. T. Fetherston, Assoc. M. Am. Soc. C. E., will be presented for discussion at this meeting.

This paper is printed in this number of *Proceedings.*

ANNUAL MEETING.

The Fifty-fifth Annual Meeting will be held at the Society House, on Wednesday and Thursday, January 15th and 16th, 1908. The Business Meeting will be called to order at 10 o'clock on Wednesday morning. The Annual Reports will be presented, officers for the ensuing year elected, members of the Nominating Committee appointed, a proposed amendment to the Constitution presented for action, the Report of the Special Committee on Rail Sections, printed in *Proceedings* of August, 1907, page 290, will be presented for discussion, and other business transacted.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Society of Engineers, 17 Victoria Street, Westminster, S. W., England.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Civil Engineers' Club of Cleveland, 718 Caxton Building, Cleveland, Ohio.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa.

Engineers' Society of Western Pennsylvania, 803 Fulton Building, Pittsburg, Pa.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

Louisiana Engineering Society, 604 Tulane-Newcomb Building, New Orleans, La.

Engineers' Club of Central Pennsylvania, Corner Second and Walnut Streets, Harrisburg, Pa.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Teknisk Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Société des Ingénieurs Civils de France, 19 Rue Blanche, Paris, France.

Svenska Teknologföreningen, Brunkebergstorg 18, Stockholm, Sweden.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Pacific Northwest Society of Engineers, 617–618 Pioneer Building, Seattle, Wash.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Memphis Engineering Society, Memphis, Tenn.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

The Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Cleveland Institute of Engineers, Middlesbrough, England.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Rochester Engineering Society, Rochester, N. Y.
Brooklyn Engineers' Club, 197 Montague Street, Brooklyn, N. Y.
Montana Society of Engineers, Butte, Montana.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendix* to the Annual Report of the Board of Direction for the year ending December 31st, 1906, contains a summary of all searches made to that date.

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*_Proceedings_, Vol. XXXIII. p. 20 (January, 1907).

ACCESSIONS TO THE LIBRARY.

(From October 8th to November 11th, 1907.)

DONATIONS.*

FORMULES, TABLES ET RENSEIGNEMENTS USUELS.

Aide-Mémoire des Ingénieurs, des Architectes, etc., Partie Pratique. Par J. Claudel. Onzième Edition Entièrement Refondue, Revue et Corrigée par de Nombreux Collaborateurs sous la Direction de Georges Daries. Paper, 9 x 6 in., illus., 2 vol. Paris, H. Dunod et E. Pinat, 1907. 30 francs.

The first edition of this handbook for engineers and constructors was published in 1846, since which time eleven editions have been issued. In the preparation of the present volumes, M. Daries has followed the lines originally laid down by the author, being assisted by a number of engineers, each of whom is a specialist in his work. The subject-matter has been thoroughly revised and brought up to date by the addition of new chapters and 868 new figures. Such subjects of current interest as hydraulics, hydraulic motors, the distribution of water, electricity, lighting, steam engines and boilers, steam and gas turbines, roads, bridges, railroads, automobiles, steel construction, reinforced concrete, etc., have received special attention. The formulas and problems are given in a clear and precise manner, and have the added value of having been used in French technical schools and Engineering Departments. The Contents are: Mécanique; Résistance des Matériaux; Hydraulique; Moteurs Hydrauliques; Distributions d'Eau; Assainissement; Physique Industrielle; Electricité; Routes et Canaux; Calcul et Construction des Ponts; Moteurs a Vapeur et a Gaz; Chemins de Fer; Architecture; Matériaux de Construction; Fondations; Constructions Civiles; Appendice. At the end of the second volume there is an index of twenty-eight pages.

STEAM BOILERS AND SUPPLEMENTARY APPLIANCES.

A Practical Treatise on Their Construction, Equipment and Working. By William H. Fowler. Cloth, 9 x 6 in., illus., 12 + 619 + 14 pp. Manchester, England, The Scientific Publishing Company. 12 shillings 6 pence net.

This volume, it is stated, is the result of thirty years' study and practical experience in boiler design, inspection, and construction on the part of the author. In it he has endeavored to supply a book which will prove useful to the steam user, the works manager, the boiler inspector and the man in charge of the boiler alike, and one which will show the relative advantages and disadvantages of a particular arrangement or piece of apparatus and teach not only the "how," but also the "why." The design of boilers, with a brief outline of the strength and properties of materials, as well as the principles of construction, are discussed in the first two chapters. The principal types of boilers and fittings, including Continental and American as well as British types, are next described, followed by chapters on steam traps, valves, feed pumps, indicators, etc., with special attention to filtering and softening of feed water and the superheating of steam. Under the section on fuel, mechanical stokers are described, with a discussion of the principles of combustion and the application of oil fuel. Several chapters are devoted to hydraulic tests and boiler evaporation trials, and to the causes and prevention of defects due to the wear and tear of boilers. The concluding chapter deals with the qualifications and duties of those engaged in the inspection of boilers, which, in Great Britain, is performed by staffs of engineers attached to boiler insuring and inspecting companies. The Chapter headings are: Materials Used in Construction; Strength of Boilers; Lancashire and Cornish Boilers and Their Modification; Vertical Boilers; Locomotive Boilers; Externally-Fired Boilers; Marine Boilers; Water-Tube Boilers; Heating Boilers and Steaming Vessels; Steam Stop Valves and Steam Dryers; Safety Valves; Feed, Blow-out and Scum Valves; Water Gauges, Alarms, Fusible Plugs; Pressure Gauges; Steam-Pipe Arrangements; Steam Traps; Reducing Valves; Feed Pumps and Injectors; Feed-Water Heaters and Evaporators; Filtering and Softening Feed Water; Superheating and Superheaters; Fuels and Combustion; Boiler Furnaces; Mechanical Stokers; Draught: Its Production and Regulation; Use of Oil Fuel; Non-Conducting Coverings for Steam Pipes; Corrosion in Boilers; Defects in Boilers; Hydraulic Tests; Boiler Evaporative Tests; Boiler Inspection. There is an index of fourteen pages.

* Unless otherwise specified, books in this list have been donated by the publisher.

LE DÉTROIT DE PANAMA.

Documents Relatifs à la Solution Parfaite du Problème de Panama (Détroit Libre, Large et Profond). Ces Documents Renferment des Détails sur la Solution très Imparfaite Adoptée par les Etats-Unis (Canal à Ecluses) et sur les Mauvais Résultats des trois premières Années de Travaux du Gouvernement Américain. Par Philippe Bunau-Varilla. Paper, 10 x 6½ in., illus., 305 pp. Paris, H. Dunod et E. Pinat, 1907. 10 francs.

The first part of this book is devoted to a comparison of the work accomplished by the old French Panama Canal Company from 1881 to 1888 with that done by the American Government from 1904 to 1907. This is followed by a report of the technical discussion of the subject before the Society of Arts, on January 23d, 1907, in London, England, together with the text of two letters addressed to President Roosevelt by the author. The second part comprises a statement by the author before the Board of Consulting Engineers as to the various problems connected with the construction of the Panama Canal. There is also contained reports of the Board of Consulting Engineers on the author's design for the canal; on the attitude of President Roosevelt before and after the report of the Board, etc. The author, it is stated, refutes the objections of the American engineers to a sea-level canal and concludes in favor of the original French project.

THE DESIGN AND CONSTRUCTION OF DAMS.

Including Masonry, Earth, Rock-Fill, Timber and Steel Structures. Also the Principal Types of Movable Dams. By Edward Wegmann, M. Am. Soc. C. E. Fifth Edition, Revised and Enlarged. Cloth, 12 x 9 in., illus., 13 + 421 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907. $6.00. (Donated by the Author.)

The first edition of this work was published in 1888 as a treatise on "The Design and Construction of Masonry Dams"; since that time four other editions, including the present one, have been issued. The subject-matter contained in this edition has been thoroughly revised and brought up to date. In Part I, which treats of the design and construction of masonry dams and which formed the original work, the latest theories of design are given. Descriptions of all the important dams built, or in the course of building, are given, and in the case of the New Croton Dam and a few others, the construction is described with considerable detail. Part II treats of fixed dams other than masonry, and Part III is devoted to descriptions of movable dams. The new matter added to these parts consists of descriptions of steel and concrete-steel dams, high earth dams, Stoney sluice-gates and rolling dams. The Appendix contains the Specifications for the New Croton Dam; twenty-five tables giving the dimensions and strength of various profile types, proofs of the principles discussed, and practical examples of the methods proposed for designing profiles, etc.; and a bibliography of the various types of dams described by the author. The book is illustrated by 120 figures in the text, by 34 half-tone plates and 100 folders, and there is an index of six pages. The Contents are: Part I, Design and Construction of Masonry Dams: Introduction; Distribution of Pressure in a Wall of Masonry; Theoretical Profiles; Various Applications of Equations (1) to (14); Practical Profiles; Construction; Spanish Dams; French Dams; Dams in Various Parts of Europe; Dams in Algiers; Dams in Egypt; Dams in Asia and Australasia; American Dams; Reinforced Concrete Dams. Part II, Earthen, Rock-Fill, Timber and Steel Dams: Earthen Dams; Dams Made by the Hydraulic Process; Rock-Fill Dams; Timber Dams; Steel Dams. Part III, Movable Dams: Frame Dams; Shutter Dams; Dams With Bear-Trap Gates; Stoney Roller Sluice-Gates, Rolling Dams, and Butterfly Dams; Recent Movable Dams; Appendix.

FOWLER'S MECHANICAL ENGINEER'S POCKET BOOK, 1908.

Edited by William H. Fowler. Tenth Annual Edition, Revised and Greatly Enlarged. Leather, 6 x 4 in., illus., 674 pp. Manchester, England, Scientific Publishing Co., 1907. 2 shillings 6 pence.

The contents of this edition, it is stated, have been thoroughly revised and greatly enlarged, the subject-matter having been rearranged in specific sections. The matter relating to building and building materials, which is now included in the special "Handbook for Architects and Builders," has been omitted from this publication. This is also true of that relating to machine tools and processes, which is to be published in a handbook specially devoted to workshop practice. Special attention has been given to the section relating to steam boilers and engines,

and much that is new has been added. There is also a new section dealing with pumps and pumping machinery, making the present volume exceed the previous editions by 100 pages. There is an index of twenty-eight pages.

RAILWAY CORPORATIONS AS PUBLIC SERVANTS.

By Henry S. Haines, M. Am. Soc. C. E. Cloth, 8 x 5½ in., 9 + 233 pp. New York, The Macmillan Company; London, Macmillan & Co., Ltd., 1907. $1.50. (Donated by the Author.)

The substance of this work was presented first as a course of lectures at the Boston University School of Law in May, 1907. It is stated in the preface that the work supplements, to some extent, a previous work on "Restricted Railway Legislation," as it describes the development of such legislation since the passage of the Act to Regulate Inter-state Commerce. The author discusses the question with regard to the amelioration of the relations existing between railway corporations and the public and considers "how they are affected as to their rights, powers, privileges, and obligations by reason of the duty which they owe to the community from being engaged in a public service." The Contents are: The Nature of a Public Service; The Public Service of a Railway; The Public Benefits Conferred by Railways; The Public Burdens Imposed by Railways; Recent Federal Legislation; The Results of Ineffectual Control of Railway Corporations; The Reasonableness of Railway Rates; The Standard of Railway Service; The Proper Regulation of Railway Service. There is an index of seven pages.

TABLES OF QUANTITIES FOR PRELIMINARY ESTIMATES.

By E. F. Hauch and P. D. Rice. Cloth, 7 x 4 in., illus., 3 + 92 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907. $1.25 net.

It has been the endeavor of the authors to make the scope of these tables broad enough to meet the requirements of the locating engineer and to present them in a form convenient for field use. Five, and in some cases, seven place logarithms have been used in the calculations, which, the authors state, have been carefully made. The formulas and methods of calculation are given so that tables for special cases may be readily prepared. To facilitate this, a table of second differences for prismoids and wedges, and of second and third differences for quarter cones, has been added. A few tables, other than those pertaining to earthwork, have also been included.

CLEAN WATER AND HOW TO GET IT.

By Allen Hazen, M. Am. Soc. C. E. Cloth, 8 x 5½ in., illus., 10 + 178 pp. New York, John Wiley & Sons, 1907. $1.50. (Donated by the Author.)

The subject-matter contained in this little book is stated by the author to be especially intended for mayors and aldermen and for those who have the power to bring about better conditions in regard to water-works and their management. The means now used by American cities to secure clean water are briefly discussed, with the application of these means to new problems. Closely allied subjects, such as matters of general policy, pressure and fire service, the sale of water, and the financial management of water-works, are also discussed. The Chapter headings are: Impounding Reservoir Supplies; Water Supplies from Small Lakes; Supplies from Great Lakes; Water Supplies from Rivers; Ground Water Supplies; On the Action of Water on Iron Pipes and the Effect Thereof on the Quality of the Water; Development of Water Purification in America; On the Nature of the Methods of Purifying Water; On the Application of the Methods of Water Purification, Arranged According to the Matters to be Removed by the Treatment; Storage of Filtered Water; On the Required Sizes of Filters and Other Parts of Water-Works; As to the Pressure Under Which Water is to be Delivered; On the Use and Measurement of Water; Some Financial Aspects; The Laying Out and Construction of Works; On the Financial Management of Publicly Owned Water Works. There is an index of four pages.

PRINCIPLES OF REINFORCED CONCRETE CONSTRUCTION.

By F. E. Turneaure, Assoc. M. Am. Soc. C. E., and E. R. Maurer. Cloth, 9 x 6 in., illus., 8 + 317 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907. $3.00.

The contents of this work are divided into two parts. The first part, Chapters I to VI, treats of the theory of the subject and presents the results of experiments.

Chapter I contains a brief historical sketch of reinforced concrete with a discussion of its uses and advantages as a form of construction. This is followed by a chapter on the properties of plain concrete and steel, which includes a discussion of the subjects of adhesion and relative contraction and expansion. The theoretical treatment of reinforced concrete is then considered, and all available tests on beams and columns are presented, together with the formulas and diagrams necessary in practice. The second part, Chapters VII to X, treats of the application of reinforced concrete to building construction, but only such illustrative material for actual design is given as is needed to make clear the principles involved, references being given in the text to works by other authors, which treat of the subject more fully. In the Chapter on Arches, the authors have given a complete general analysis of the solid arch rib, which, they believe, offers advantages over the usual graphical method. The Contents are: Introductory; Properties of the Material; General Theory; Tests of Beams and Columns; Working Stresses and General Constructive Details; Formulas, Diagrams and Tables; Building Construction; Arches; Retaining-Walls and Dams; Miscellaneous Structures. There is an index of three pages.

Gifts have also been received from the following:

Am. Inst. of Elec. Engrs. 1 bound vol.
Argollo, M. de T. e. 1 pam.
Assoc. of Am. Portland Cement Mfrs. 3 pam.
Atchison, Topeka & Santa Fe Ry. Co. 1 pam.
Bangor & Aroostook R. R. Co. 1 pam.
Bengal, India-Under Secy. to the Govt. 1 bound vol., 1 vol.
Berg, W. G. 3 bound vol.
Bibliotheek der Technische Hoogeschool te Delft. 2 vol.
Brit. Fire Prevention Comm. 2 bound vol.
Canada-Dept. of Marine and Fisheries. 2 vol., 2 pam.
Canada-Dept. of the Interior. 6 maps.
Canada-Geol. Survey. 4 bound vol., 14 vol.
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India-Office of the Supt. of Govt. Printing. 1 vol.
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Lake Mohonk Conference on Inter. Arbitration. 1 vol.
Louisville & Nashville R. R. Co. 1 pam.
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Lynn, Mass.-City Messenger. 1 bound vol.
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Natal-Govt. Railways. 1 vol.
National Assoc. of Cement Users. 1 vol.
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***New York City Record.* 1 bound vol.**
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Preussische Landesanstalt für Gewässerkunde. 3 vol.
Purdon, C. D. 1 pam.
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Smithsonian Institution. 1 vol.
Soc. of Ry. Club Secretaries. 1 pam.
Sprague, F. J. 1 pam.
***Street Railway Journal.* 1 vol.**
Switzerland-Eidgen. Hydrometrisches Bureau. 2 vol.
Texas Academy of Sci. 1 pam.
Transvaal-Mines Dept. 1 vol.
Trussed Concrete Steel Co. 1 bound vol.
U. S. Bureau of Statistics. 4 pam.
U. S. Bureau of the Census. 1 bound vol., 1 vol.
U. S. Corps of Engrs. 10 specif.
U. S. Forest Service. 6 pam.

U. S. Geol. Survey. 80 pam.
U. S. Interstate Commerce Comm. 4 pam.
U. S. Lake Survey Office. 3 maps, 1 pam.
U. S. Office of Exper. Stations. 6 pam.
U. S. Office of Public Roads. 1 pam.
U. S. Reclamation Service. 1 pam.
Univ. of Cal.-Agri. Exper. Station. 1 pam.
Wabash R. R. Co. 1 pam.
Western Australia-Dept. of Mines. 1 bound vol.
Western Australia-Geol. Survey. 3 vol.
Wis.-Geol. and Natural History Survey. 2 bound vol., 1 vol.

BY PURCHASE.

Recherches sur l'Epuration Biologique et Chimique des Eaux d'Égout. Effectuées à l'Institut Pasteur de Lille et à la Station Expérimentale de la Madeleine. Par Le Dr. A. Calmette, avec la collaboration de MM. E. Rolants, F. Constant, E. Boullanger, L. Massol et M. le Professeur A. Buisine. 2 vol. Paris, Masson et Cie., 1905, '07.

Locomotive Compounding and Superheating. A Practical Text-Book for the Use of Railway and Locomotive Engineers, Students, and Draughtsmen. By J. F. Gairns. London, Charles Griffin & Company, Limited, 1907.

The Building Mechanics' Ready Reference. Stone and Brick Masons' Edition. By H. G. Richey. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907.

Electricity in Mining. By Sydney F. Walker. New York, D. Van Nostrand Company, 1907.

The Marine Steam Turbine. A Practical Description of the Parsons Marine Turbine as Presently Constructed, Fitted, and Run, Including a Description of the Denny & Johnson Patent Torsion Meter for Measuring the Transmitted Shaft Horse-Power, and Containing Fifty Questions (with Solutions) on Elementary Turbine Design. By J. W. Sothern. Second Edition. New York, D. Van Nostrand Company; London, E. C. Whittaker & Co., 1906.

A Treatise on Hydraulics. By William Cawthorne Unwin. London, Adam and Charles Black, 1907.

Cement and Concrete. By Louis Carlton Sabin, M. Am. Soc. C. E. Second Edition, Revised and Enlarged. New York, McGraw Publishing Company, 1907.

How to Lay Out Suburban Home Grounds. By Herbert J. Kellaway. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907.

Ordnance and Gunnery. A Text-Book Prepared for the Cadets of the United States Military Academy, West Point. By Ormond M. Lissak. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907.

Die Maschinen-Elemente, ihre Berechnung und Konstruktion mit Rücksicht auf die Neueren Versuche. Von C. Bach. In Zwei Bänden. Erster Band: Text; Zweiter Band: Tafeln und Tabellen. Stuttgart, A. Kröner, 1903.

SUMMARY OF ACCESSIONS.

From October 8th to November 11th, 1907.

Donations (including 16 duplicates)	210
By purchase	12
Total	222

MEMBERSHIP.

ADDITIONS.

(October 9th to November 11th, 1907.)

MEMBERS.

	Date of Membership.
ANTHONY, CHARLES CHAPMAN. Asst. Signal Engr., P. R. R. Co., Broad St. Station, Philadelphia, Pa	Oct. 2, 1907
DALTON, B. J. Assoc. Prof., Civ. Eng., Univ. of Kansas, 1220 Tenn St., Lawrence, Kans	Oct. 2, 1907
GAULT, HOMER JOHNSTON. Painesville, Ohio	Oct. 2, 1907
HARTE, CHARLES RUFUS. Asst. Engr., N. Y., N. H. & H. R. R. Co., Room 308, R. R. Bldg., New Haven, Conn Jun. Assoc. M. M.	 April 4, 1899 May 2, 1900 Nov. 5, 1907
JONAS, HENRY F. P. O. Box 583, Houston, Tex	Oct. 2, 1907
KERNOT, MAURICE EDWIN. Acting Engr.-in-Chf., Victorian Railways, Railway Dept., Spencer St., Melbourne, Victoria, Australia	June 5, 1907
KNOBLOCH, WALSTAN EMILE. U. S. Asst. Engr., 1539 Louisiana Ave., New Orleans, La	Oct. 2, 1907
KROEBER, ADOLF THOMAS. Care, Hering & Fuller, 170 Broadway, New York City	Oct. 2, 1907
McCARTHY, GEORGE ARNOLD. Chf. Engr., Temiskaming & Northern Ontario Ry., Box 465, North Bay, Ont., Canada	Nov. 6, 1907
McKAY, HOOD. Div. Supt., Eastern Div., The Lehigh Coal & Navigation Co., Lansford, Carbon Co., Pa	Nov. 6, 1907
MITCHELL, STEPHEN ARNOLD. Chf. Engr., Kansas City Water Works, 202 Sheidley Bldg., Kansas City, Mo	Oct. 2, 1907
NEWELL, JOSEPH PETTUS. 33 Washington Bldg., Portland, Ore.	Oct. 2, 1907
PHELPS, WILLIAM COLLINS. 21 Park Row, Room 2324, New York City	Oct. 2, 1907
SCHULZE, HENRY ATHERTON. Archt., 82 Second St., San Francisco, Cal	Oct. 2, 1907
SHAND, JAMES. Obras del Puerto, Coatzacoalcos, Mexico	Oct. 2, 1907
SNOW, JESSE BAKER. Asst. Engr., Penn., N. Y. & L. I. R. R., East River Tunnels, 345 East 33d St., New York City	Oct. 2, 1907
STAYTON, EDWARD MOSES. 423 East Kansas St., Independence, Mo Assoc. M. M.	 Feb. 4, 1903 Nov. 5, 1907
VENABLE, WILLIAM MAYO. Div. Engr., Key West Extension, Florida East Coast Ry., Miami, Fla Assoc. M. M.	 Sept. 4, 1901 Oct. 1, 1907
WAITE, GUY BENNETT. Gen. Mgr. and Treas., Standard Concrete Steel Co., 100 Broadway, New York City Assoc. M. M.	 May 2, 1894 Nov. 5, 1907

MEMBERS (*Continued*). Date of Membership.

WEEKS, WILLIAM CHARLES. Supt. of Constr., Washington Water Power Co., Spokane, Wash. .... Oct. 2, 1907

WINSLOW, BENJAMIN EMANUEL. Cons. Architectural Engr., 1615 Ashland Blk., Chicago, Ill. .... Oct. 2, 1907

ASSOCIATE MEMBERS.

ALEXANDER, KAY. Res. Engr., N. P. Ry., St. Regis, Mont... Oct. 2, 1907

ALLISON, CALVIN TOMKINS. Gen. Contr., Jones Bldg., Haverstraw, N. Y. .... May 1, 1907

BENSON, NEWTON DAVIS. 710 Banigan Bldg., Providence, R. I. .... July 10, 1907

BROWNELL, LEONARD DEMPSTER. 118 Cannon St., Syracuse, N. Y. .... Nov. 6, 1907

CAMERON, HARRY FRANK. Byfield, Mass. .... Oct. 2, 1907

CHACE, IRA MASON, JR. P. O. Box 553, Tucson, Ariz. .... Oct. 2, 1907

CHADBOURNE, EDWARD MERRIAM. Gen. Mgr., Clinton Fire Proofing Co. of California, 833 Monadnock Bldg., San Francisco, Cal. { Jun. Nov. 3, 1903; Assoc. M. Oct. 2, 1907 }

CHAMBERLAINE, ROBERT LLOYD. 1621 St. Paul St., Baltimore, Md. .... Oct. 2, 1907

CHIPMAN, PAUL. Care, Canadian White Co., Ltd., Sovereign Bank Bldg., Montreal, Que., Canada .... Oct. 2, 1907

DAVIS, GEORGE JACOB, JR. Instr. in Civ. Eng., Univ. of Wisconsin, 1731 Regent St., Madison, Wis. .... { Jun. Nov. 4, 1902; Assoc. M. Oct. 2, 1907 }

DOWNER, THOMAS BENSON. Asst. Engr., Los Angeles Aqueduct, Lone Pine, Cal. .... Oct. 2, 1907

FISHER, CHESTER CENTENNIAL. Asst. Engr., U. S. Reclamation Service, R. F. D. No. 2, Meridian, Idaho .... { Jun. April 3, 1906; Assoc. M. Oct. 2, 1907 }

FISHER, WAGER. Civ., Elec. and Mech. Engr., 1233 New Land Title Bldg., Philadelphia, Pa. .... { Jun. Oct. 3, 1899; Assoc. M. Nov. 6, 1907 }

FORREST, GEORGE MUNRO. 132 West 47th St., New York City .... Oct. 2, 1907

GAY, LEON LINCOLN. Asst. Engr., U. S. Reclamation Service, Boise, Idaho .... { Jun. Dec. 5, 1905; Assoc. M. Oct. 2, 1907 }

HOSMER, GUY FREDERIC. Cousins Hotel, Old Town, Me. ..... Nov. 6, 1907

INGRAM, WILLARD EDWARD. Prin. Asst. Structural Engr., The Arnold Co., 181 La Salle St., Chicago, Ill. .... Oct. 2, 1907

JORDAHL, ANDERS. Chf. Engr., Concrete Dept., W. S. Barstow & Co., 50 Pine St., New York City .... Nov. 6, 1907

KEITH, LORIN ACIL. City Engr.'s Office, Mansfield, Ohio.... Oct. 2, 1907

LATHROP, JAY COWDEN. Room 1110, Flood Bldg., San Francisco, Cal. .... Oct. 2, 1907

ASSOCIATE MEMBERS (*Continued*).

		Date of Membership
MORSE, HOWARD SCOTT. Care, U. S. Reclamation Service, La Mesa, via Glendive, Mont.		Oct. 2, 1907
OAKLEY, GEORGE ISRAEL. Asst. Engr., N. Y. State Barge Canal, Residency No. 4, Little Falls, N. Y.	Jun. Assoc. M.	Oct. 6, 1903 Nov. 6, 1907
PERRING, HENRY GARFIELD. 16 So. Broad St., Philadelphia, Pa.		Nov. 6, 1907
RAVENSCROFT, EDWARD HAWKS. 1761 Monadnock Bldg., Chicago, Ill.		Nov. 6, 1907
STARR, HERBERT HARRIS. 42 Church St., New Haven, Conn.		Oct. 2, 1907
SUSSEX, JAMES WOLFE. Wenatchee, Wash.	Jun. Assoc. M.	Oct. 6, 1903 Oct. 2, 1907
THROOP, GEORGE HUNTINGTON. Care, J. G. White & Co., 43 Exchange Pl., New York City		May 1, 1907
WHITMAN, RALPH. Asst. Civ. Engr., U. S. N., Navy Yard, League Island, Pa.		Nov. 6, 1907

ASSOCIATE.

MORRIS, DAVIS HARRINGTON. 225 W. Monument Ave., Dayton, Ohio	Nov. 6, 1907

JUNIORS.

BELLOWS, SIDNEY RAYMOND. Conimicut, R. I.	Oct. 1, 1907
BISHOP, HIRAM NELSON. Clinton, Mont.	Oct. 1, 1907
BREWER, WILLARD SEYMOUR. 800 Main St., Hartford, Conn.	Sept. 3, 1907
COOMBS, ARTHUR WELLESLEY. 135 Remsen St., Brooklyn, N. Y.	Oct. 1, 1907
DIMMLER, CHARLES LOUIS. 2632 Durant Ave., Berkeley, Cal.	Oct. 1, 1907
FLEMING, THOMAS, JR. Asst. Engr., Penn. Dept. of Health, 501 N. Front St., Harrisburg, Pa.	Nov. 5, 1907
FOSTER, HERBERT BISMARCK. C. E. Bldg., Room 101, Univ. of California, Berkeley, Cal.	Sept. 3, 1907
HALCOMBE, NORMAN MARSHALL. Box 250, Stanford University, Cal.	Sept. 3, 1907
HERSEY, GUY ALFRED. Bridge Engr., Aroostook Constr. Co., Medford Center, Me.	June 4, 1907
HOLMES, ROBERT LESLIE. Boyce, La.	Oct. 1, 1907
HURDLE, REGINALD TRUMAN. Care, U. S. Reclamation Service, Crane Cr. Camp, Tokna, Mont.	Oct. 1, 1907
MILLER, HAROLD EDMUND. 110 Dexter St., Providence, R. I.	Oct. 1, 1907
MONTERO, JULIO DANIEL. Güines, Cuba	Oct. 1, 1907
NELSON, JABEZ CURRY. Care, Ford, Bacon & Davis, Birmingham, Ala.	Oct. 1, 1907
NOYES, STEPHEN [illegible] 15 Francis St., Newport, R. I.	Oct. 1, 1907
ROBBINS, HALL[illegible] shington Ave., Albany, N. Y.	Nov. 5, 1907

JUNIORS (*Continued*).

	Date of Membership.
SCOTT, JOHN KUHN. 5470 Black St., Pittsburg, Pa........	Oct. 1, 1907
VOGEL, JOHN LEONARD. 185 Grant Ave., Jersey City, N. J..	Nov. 5, 1907
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WOERMANN, JOHN WILLIAM. Res. Engr. in Charge of Constr., Morris Hydro-Electric Plant, R. F. D. No. 3, Minooka, Ill.

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ASSOCIATE MEMBERS (*Continued*).

ARMITAGE, GEORGE WASHINGTON. Dept. of Civil Constructions, Public Works, Arsenal, Havana, Cuba.

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BILLINGS, ASA WHITE KENNEY. P. O. Box 110, Santiago de Cuba, Cuba.

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BUTCHER, WILLIAM LARAMY. With Metcalf & Eddy, Cons. Engrs., 14 Beacon St., Boston, Mass.

CHAPMAN, PAUL. Room 722, Park Row Bldg., New York City.

COUCHOT, MAURICE CHARLES. 604 Mission St., San Francisco, Cal.

DANIELS, THOMAS REMINGTON HOLDEN. Care, Indianapolis Traction & Terminal Co., Indianapolis, Ind.

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GREEN, CHARLES NEWTON. Asst. Engr., Rapid Transit Comm., 154 Nassau St., New York City.

GRISWOLD, RAY ELLIOTT. Drain, Ore.

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JOHNSTON, JOHN PARRY. 32 West 40th St., New York City.

KAST, CLARKE NIGHTINGALE. Locating Engr., C., M. & St. P. Ry., 01423 Mill St., Spokane, Wash.

KING, EVERETT EDGAR. Stillwater, Okla.

LEE, JOHN LOUIS. Castleton, Vt.

LIGHTFOOT, WILLIAM JOSEPH. 519 Osage Ave., Manhattan, Kans.

LOVETT, GEORGE FREDERICK. Berlin, N. H.

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MACNAIR, HENRY JAMES. Map Builder, 112 Water St., Boston, Mass.

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MURRAY, CHARLES WARREN. Cordele, Ga.

NORTH, ARTHUR TAPPAN. Care, The McArthur Bros. Co., Fisher Bldg., Chicago, Ill.

PAINE, HIBBARD ATWILL. Odessa, N. Y.

RICE, HERBERT ALLAN. Assoc. Prof., Civ. Eng., Univ. of Kansas, 800 Indiana St., Lawrence, Kans.

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ROBB, LOUIS ADAMS. 71 Lincoln Park, Newark, N. J.

SARGENT, JOSEPH ANDREWS. Ingeniero Jefe, 1*a*, Obras Publicas, Manzanillo, Cuba.

ASSOCIATE MEMBERS (*Continued*).

SHEDD, GEORGE GARNETT. Care, John R. Freeman, 815 Banigan Bldg., Providence, R. I.

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SIMPSON, ERASTUS ROLAND. 16 Cumberland St., Boston, Mass.

SKINNER, FREDERICK GARDINER. Seattle, Wash.

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TERRELL, WILLIFORD HARRY. Clyde, N. C.

TRACY, LOUIS DOWNER. Civ. and Min. Engr., 245 Fourth Ave., Pittsburg (Res., 108 Lincoln Ave., Edgewood Park, Allegheny Co.), Pa.

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ASSOCIATES.

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TURRILL, SHERMAN MARSH. 4227 Hamilton Ave., Cincinnati, Ohio.

JUNIORS.

ADEY, JOHN SEAGER. 1340 Madison Ave., New York City.

ALDERSON, WILLIAM HOWARD. Care, J. D. Isaacs, 135 Adams St., Chicago, Ill.

ALLEN, CHESTER SALISBURY. Care, United Fruit Co., Bocas del Toro, Panama.

BAKER, HAROLD JAMES MANNING. Fort Ward, via Port Blakeley, Wash.

BARLOW, ALFRED EUGENE, JR. 220 West 105th St., New York City.

CAMPBELL, HENRY AVERY. 787 Market St., Room 225, San Francisco, Cal.

CARLISLE, ORVILLE BERTON. 169 West 81st St., New York City.

CARTER, LESTER LEVI. Box 1154, Fresno, Cal.

COOPER, FRANK WESLEY. Res. Shop Insp. of Bridges, West. Pac. Ry. Co., 4414 Fifth Ave., East End, Pittsburg, Pa.

CORP, HENRY WILLIAM. 24 Everett Ave., Providence, R. I.

CROWELL, FRANCIS STIRLING. 188 Franklin Pl., Flushing, N. Y.

EDWARDS, DEAN GRAY. Care, Board of Water Supply, Walden, N. Y.

ESTEN, HOWARD FOSS. 128 Cedar St., Pawtucket, R. I.

GILLEN, WALTER JOSEPH. Asst. Engr., Board of Water Supply, New York City, Brown Station, Ulster Co., N. Y.

HALE, HERBERT MILLER. Asst. Engr. Designer, Board of Water Supply, 299 Broadway, New York City.

HANSEN, PAUL. Asst. Engr. to the State Board of Health of Ohio, 912 Harrison Bldg., Columbus, Ohio.

JUNIORS (*Continued*).

HARRISON, RUSSELL EDWIN. With A. H. Smith, Cons. Engr., 322 The Nasby, Toledo, Ohio.

HARVEY, MICHAEL SMITH. Auburn, Ala.

HAVENS, VERNE LEROY. Care, Mex. Tram. Co., Mexico (Indianilla), Mexico.

HAYES, CHARLES EDWARD. Station A, Superior, Wis.

HEDDEN, EVERETT BURR. 30 Orawanpum St., White Plains, N. Y.

HERRON, GEORGE MERRICK. P. O. Box 1054, Palo Alto, Cal.

HOHL, LEONARD LOUIS. 417 Kohl Bldg., San Francisco, Cal.

HOWE, HARRY NORTHROP. Porter Bldg., Memphis, Tenn.

MCLURE, NORMAN ROOSEVELT. Ardmore, Pa.

MERRIMAN, THADDEUS. Essex Fells, N. J.

MITCHELL, WILLIAM WASHINGTON. Res. Engr., N. P. Ry. Co., Drummond, Mont.

MOSER, ALBERT LEO BRECHT. Care, E. A. Moser, Cripple Creek, Colo.

SHELEY, HORACE WEST. Civ. and Min. Engr., P. O. Box 34, Salt Lake City, Utah.

SMITH, ROBERT MACKINLAY. Chf. Draftsman, Laclede Gas Light Co., 716 Locust St., St. Louis, Mo.

THOMSON, WARREN BROWN. 10 Moxon St., Poughkeepsie, N. Y.

TINKHAM, RALPH RUSSELL. Engr. with Russell Wheel & Foundry Co., 51 Smith Ave., Detroit, Mich.

VAN BRAKLE, JOHN OGDEN. 718 Monastery St., West Hoboken, N. J.

WATKINS, GUY ANDERSON. Asst. Engr., Terminal R. R. Assoc. of St. Louis, 206 Union Station, St. Louis, Mo.

WILCOX, FRANK LESLIE. 615 Frisco Bldg., St. Louis, Mo.

DEATHS.

CLARK, JOHN HOWARD. Elected Member, November 4th, 1903; died October 13th, 1907.

HEQUEMBOURG, CHARLES EZRA. Elected Member, June 5th, 1901; died October 17th, 1907.

OBERNDORF, PAUL ERNEST. Elected Junior, February 5th, 1907; died October 13th, 1907.

WAINWRIGHT, JONATHAN. Elected Member, February 3d, 1892; died October 11th, 1907.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(October 8th to November 11th, 1907.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Blk., Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Anales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 803 Fulton Bldg., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York, City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Electric Railway Review*, Chicago, Ill., 10c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal, London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.
(86) *Engineering-Contracting*, Chicago, Ill.
(87) *Roadmaster and Foreman*, Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.

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MUNICIPAL REFUSE DISPOSAL: AN INVESTIGATION.

By J. T. Fetherston, Assoc. M. Am. Soc. C. E.

To be Presented December 18th, 1907.

For a number of years the disposal of municipal refuse in the Borough of Richmond, New York City, has been the subject of much concern to responsible authorities. The first attempt to deal systematically with solid organic waste was made in 1895, when the former Village of New Brighton erected a Brownlee crematory, and collected garbage separated from other refuse. In 1898, the general Department of Street Cleaning introduced the separation system throughout the Borough of Richmond, and ashes, rubbish, and street sweepings were used for filling sunken lots, while garbage within economical hauling distance of a Dixon crematory (erected in 1899) was destroyed, the remainder being mixed with ashes, etc., and dumped on isolated properties. In 1902, when the city charter was amended, the collection and disposal of refuse, with other street-cleaning work, came under the control of the Borough President.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

Fig. 1.—Covered Refuse Collection Carts at Worthing.

Fig. 2.—Tipping Refuse Into Storage Hopper at Watford.

Fig. 3.—Saltley Destructor, Birmingham.

Fig. 4.—Looking Up Runway at Saltley.

The writer was placed in charge of the Bureau of Street Cleaning in 1904, and found the conditions regarding refuse disposal as follows:

1.—The separation of garbage from ashes and rubbish was imperfect. Short-haul ash dumps were sources of complaint. Land for the disposal of refuse was becoming scarce. The cremation of garbage as practiced was costly and unsatisfactory. Little trouble was experienced in the use of street sweepings for filling sunken lots, as macadam roads adjoined paved streets and the sweepings contained relatively small percentages of organic matter.

2.—The loss of short-haul dumping grounds had progressed to the point where provision for power transportation to waste lands, or some other means of final disposition of household refuse, became necessary. Efforts to obtain a reasonable rate of transportation by street railway to outlying properties failed. Examination, tests, and studies of existing garbage crematories offered no hopes of satisfying permanently the requirements of economical and sanitary final disposition. The location, population, and topography of the built-up districts under consideration rendered any means of disposal other than incineration inadvisable.

After a study of available publications on the subject, it became evident that the British method of destroying mixed refuse would solve the problem if the local refuse contained enough combustible material to consume all noxious wastes without nuisance, and provided that a reasonable degree of economy in operation could be attained.

From various books, reports, etc., the following general abstract of English practice in destroying mixed refuse was compiled:

A.—Refuse destructors are centrally located in populous districts, and are reported to be operated without nuisance.

B.—Average British household refuse consists of one-third combustible, one-third water and one-third mineral matter, by weight (Watson). This material is burned in brick furnaces by the aid of forced draft without the use of additional fuel. High temperatures are attained, and the waste gases are brought into contact with steam boilers, thus producing power which is utilized for various purposes. Each pound of average unscreened refuse will evaporate its own weight of water.

C.—The residue consists of clinker, fine ash, and dust, amounting to about one-third, by weight, of the original material. Clinker is

TABLE 1.—Composition of Refuse from Different Cities, Classified Approximately.

Description.	Fine ash, dust and dirt. Percentage.	Clinker. Percentage.	Glass, metal, etc. Percentage.	Coal, coke, breeze, and cinder. Percentage.	Garbage. Percentage.	Rubbish. Percentage.	Paper, straw and fibrous material, vegetables, bones, and offal. Percentage.	Authority.
Average Ash-bin Refuse, England........	32.00	....	3.00	51.00	....	....	14.00	Hutton.
London Refuse..........................	52.60	....	3.575	28.95	....	....	14.875	Codrington.
London Ash-bin Refuse..................	19.51	....	2.98	64.58	....	....	12.98	Russell.
Torquay, Eng., Dec. and Jan., Refuse....	25.42	....	8.17	6.51	52.42	12.29	....	Goodrich { "Disposal of Towns Refuse" p. 139.
Torquay, Eng., June Refuse..............	48.05	....	5.50	28.92	13.82	4.21	....	" " p. 141.
Berlin, Germany:								
April Refuse..........................	57.12	1.58	7.02	1.33	29.53	3.42	....	Bohm and Grohn (Hering).
August Refuse.........................	43.19	1.18	9.28	1.53	36.62	8.20	....	" " "
New York...............................	52.80	....	0.46	28.17	12.20	6.87	....	Craven (Hering).

Chemical Analysis of Berlin Refuse, by Bohm and Grohn (Hering).

Description of material.	Hygroscopic water. Percentage.	Combined water and carbonic acid. Percentage.	Combustible organic matter. Percentage.	Incombustible. Percentage.
Sifted	10.91	2.54	18.27	78.28
Coarse....................	26.55	9.53	10.20	53.72
Unsifted (computed.)..	17.62	5.54	11.94	54.90

Chemical Analysis of Refuse from Kings Norton (near Birmingham), Eng.

	Percentage.
Carbon.................	36.80
Hydrogen..............	0.29
Nitrogen..............	0.29
Sulphur................	0.19
Oxygen	7.30
Ash	41.70
Moisture...............	12.12
Total.............	98.69

Theoretical calorific value of this refuse given as 4 500 B. t. u. (From Specification, p. 26.)

Calorific Values of English Refuse Components with Average Percentage of Moisture (Dawson).

Coal......................	9 334 B. t. u
Coke.....................	8 000 "
Bones and Offal	5 334 "
Breeze and Cinder......	4 000 "
Rags.....................	3 334 "
Paper, straw, fibrous material, and vegetable refuse............	2 534 "

FIG. 1.—MIXED-REFUSE DUMP AT FOX HILLS, BOROUGH OF RICHMOND, N. Y., JUNE 27TH, 1906.

FIG. 2.—AN OLD REFUSE HEAP AT WORTHING, ENGLAND, PHOTOGRAPHED JUNE 15TH, 1906.

FIG. 3.—REFUSE ON STORAGE, LLANDUDNO, WALES, MAY 19TH, 1906.

FIG 4.—NEAR VIEW OF REFUSE AT FOX HILLS, BOROUGH OF RICHMOND, N. Y., JUNE 27TH, 1906.

useful as an aggregate in making concrete slabs, bricks, etc. If not utilized, the residue makes acceptable filling.

D.—The cost of labor and supervision per ton of refuse destroyed amounts to about 30 cents in England. The economy of the process depends to a great extent upon the utilization of the steam generated.

Up to this time (1904), all available information concerning the composition of refuse from different localities was summarized as shown in Table 1. These figures were so meager and unsatisfactory for the case in hand that only two courses were open: namely, build a destructor, with the risk of failure; or make a thorough examination of the whole question, to determine the best means of disposal should mixed refuse destruction prove unsatisfactory.

The object of this paper is to present the results of an investigation covering:

First, the quantity, composition, seasonal variations, and calorific power of local household refuse, with a series of practical tests in burning mixed wastes; and second, some data, observations, and deductions concerning a number of mixed-refuse destructors visited by the writer.

Part I.

Richmond Borough (Staten Island) has an estimated population of about 80 000, and an area of 57.2 sq. miles. It is divided into three refuse collection districts, two of which, containing the bulk of the population, are served by municipal carts, while the third, comprising the country or sparsely-settled sections, is served by hired carts.

One of the refuse collection divisions, known as the West New Brighton District, was selected as a representative portion of the borough from which to obtain the desired information concerning the problem of disposal. By actual count, there were 4 321 houses in this district, containing about 25 900 people, 90% of whom contribute wastes for removal by city carts.

The plan adopted contemplated obtaining data concerning:

I.—The quantity of refuse contributed per 1 000 inhabitants per day, by volume and by weight;

II.—The seasonal variations in quantity of refuse, by volume and by weight;

III.—The components of refuse, and their seasonal variations;

IV.—The calorific power of refuse, and its seasonal variations; also the seasonal variations in the calorific power of the components of refuse;

V.—The practical incineration of mixed refuse;

VI.—The probable temperature of the gases resulting from the destruction of refuse, and the boiler-power obtainable with seasonal variations.

Definitions.—Household refuse means practically all materials collected by municipal carts from private residences, stores, and small factories. Night-soil, dead animals, and trade refuse, such as building refuse and large manufacturing wastes, are not included.

Ashes consist mainly of the residue from domestic fires, from schools, churches, etc., and include other inorganic material, such as glass, crockery, metallic substances, dust, bricks, stones, earthenware, etc.

Garbage is composed of organic materials—vegetable and animal matter—with water and grease.

Rubbish consists of light combustible articles, such as paper, rags, excelsior, straw, wood, leather, rubber, etc.

I.—Quantity of Refuse.—Table 2 records in convenient form the quantities of different classes of household refuse as collected in the West New Brighton District.

The volumes of the different classes of refuse were obtained by careful records of cart loads. The adopted unit weights were the average results of numerous determinations. Table 2 shows that the average quantity of household refuse collected amounted to about 3.7 cu. yd. or 1.6 tons per 1 000 inhabitants per day during the period considered.

II.—Seasonal Variations in Quantity of Refuse.—Referring to Table 2, it will be noted that the volume of the total collection for any month differs slightly (from 8% above to 12% below the average), while the weight varies from 23% above the average in winter and spring to 30% below the average in summer or fall. The two classes of refuse have opposite variations by weight, "ashes and rubbish" being high in winter and low in summer, while "garbage" is low in winter and high in summer. Unseasonable weather and abnormal variations in the fuel and food supply will cause further differences in the amounts of "ashes," "rubbish," and "garbage."

TABLE 2.—HOUSEHOLD REFUSE AS COLLECTED, WEST NEW BRIGHTON DISTRICT.

Month.	Ashes and Rubbish.						Garbage.						Total Collection.			
	Volume.			Weight.			Volume.			Weight.			Volume.		Weight.	
	Cubic yards.	Percentage of 12 months' collection.	Percentage of total monthly collection.	Tons.	Percentage of 12 months' collection.	Percentage of total monthly collection.	Cubic yards.	Percentage of 12 months' collection.	Percentage of total monthly collection.	Tons.	Percentage of 12 months' collection.	Percentage of total monthly collection.	Cubic yards.	Percentage of 12 months' collection.	Tons.	Percentage of 12 months' collection.
1906.																
January	2 014	9.3	83.1	962.9	10.6	83.5	409	5.7	16.9	190.6	5.7	16.5	2 423	8.4	1 153.5	9.3
February	1 852	8.6	87.5	871.5	9.6	87.6	265	3.7	12.5	123.5	3.7	12.4	2 117	7.4	995.0	8.0
March	2 189	10.2	85.5	1 072.7	11.8	86.0	373	5.2	14.5	173.8	5.2	14.0	2 572	9.0	1 246.5	10.1
April	1 972	9.1	78.3	973.8	10.7	79.2	545	7.7	21.7	254.0	7.7	20.7	2 517	8.8	1 227.8	9.9
May	1 857	8.6	76.4	890.4	10.9	78.7	574	8.1	23.6	267.5	8.1	21.3	2 431	8.5	1 257.9	10.2
June	1 725	8.0	73.7	734.0	8.1	71.9	617	8.7	26.3	287.5	8.7	28.1	2 342	8.2	1 021.5	8.2
July	1 516	7.0	69.9	426.0	4.7	58.3	653	9.2	30.1	304.3	9.2	41.7	2 169	7 5	730.3	5.9
August	1 661	7.7	68.8	417.4	4.6	54.3	753	10.6	31.2	350.9	10.6	45.7	2 414	8.4	768.3	6.2
September	1 677	7.7	65.3	429.1	4.7	50.9	889	12.5	34.7	414.3	12.5	49.1	2 566	8.9	843.4	6.8
1905.																
October	1 567	7.2	66.1	564.7	6.2	60.1	803	11.3	33.9	374.2	11.3	39.9	2 370	8.2	938.9	7.6
November	1 678	7.8	72.0	759.8	8.4	71.4	652	9.2	28.0	303.8	9.2	28.6	2 330	8.1	1 063.6	8.6
December	1 894	8.8	76.7	877.5	9.7	76.6	574	8.1	23.3	267.5	8.1	23.4	2 468	8.6	1 145.0	9.2
Totals	21 612	100		9 079.8	100		7 107	100		3 811.9	100		28 719	100	12 891.7	100
Percentage of total collection	75.2			73.3			24.8			26.7			100		100	
Average amount per 1 000 inhabitants per day	2.77			1.164			0.91			0.425			3.68		1.589	

NOTE.—One ton = 2 000 lb. { Daily collection of refuse, except Sundays and holidays. Average weights per cubic yard; ashes and rubbish = 0.42 ton; garbage = 0.466 ton.

III.—Components of Refuse and Their Seasonal Variations.—Mechanical analyses, by weight, of the two classes of refuse shown in Table 2 were made during 1904, 1905, and 1906, as often as other work permitted. Cart loads of "ashes and rubbish," amounting to

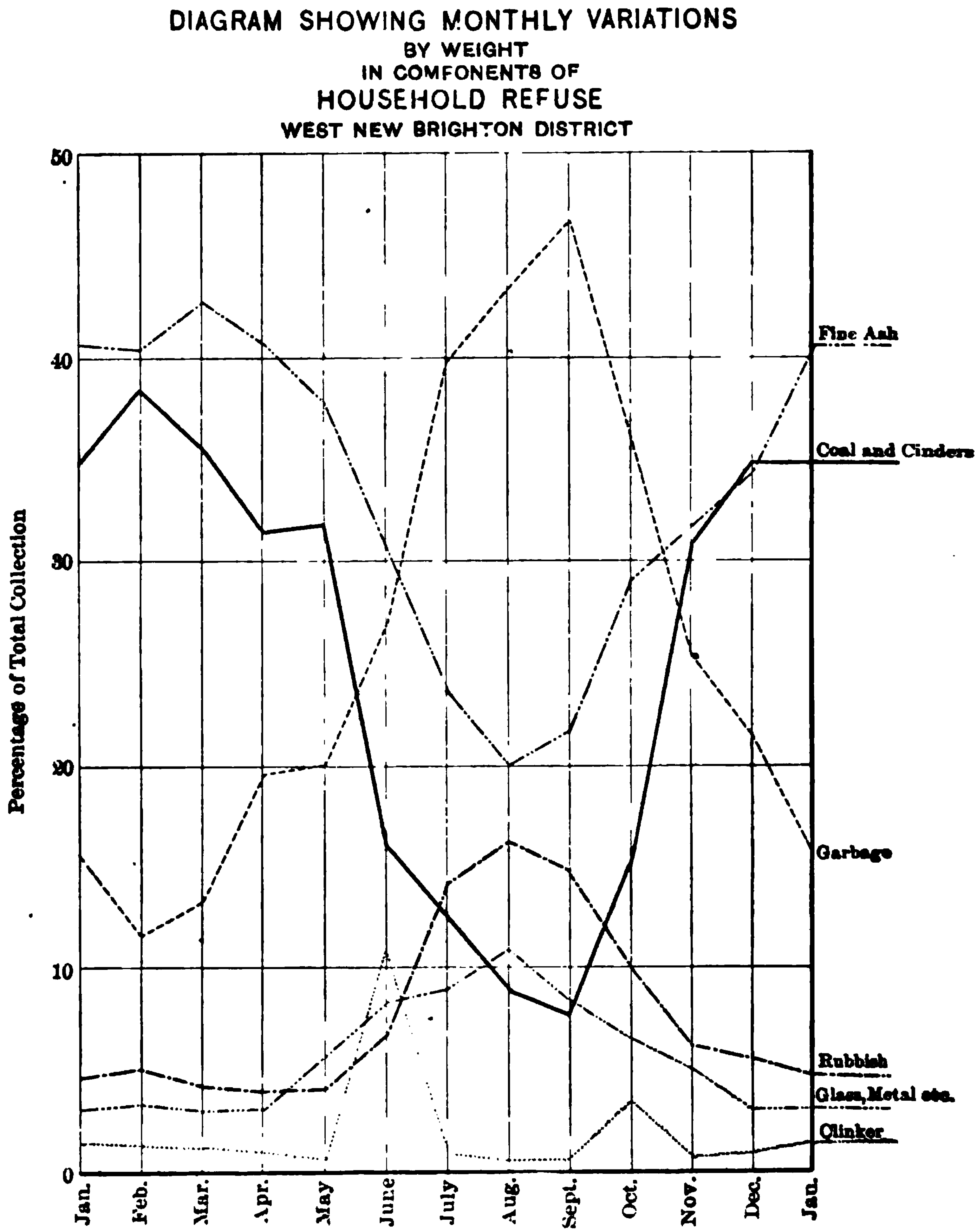

FIG. 1.

107 907 lb., from different portions of the district, were analyzed, and 562 samples of garbage, amounting to 28 101 lb., were separated into components. A ⅜-in. mesh screen was used to divide the "ashes and rubbish," the material passing through the screen being termed

Fig. 1.—Bermondsey Destructor in Rear of Town Hall.

Fig. 2.—Another View, Showing Location, Bermondsey Destructor.

Fig. 3.—Sheerness Destructor. A School House is only 8 Ft. Away from the Refuse Storage Room.

Fig. 4.—View from Water Tower at Sheerness, Showing Surroundings of Destructor.

"fine ash," while "coal and cinders" were the materials rejected by the screen and not otherwise classified as "rubbish," "clinker," "glass, metal, etc.," separated by hand-picking. Small samples (averaging 50 lb. each) of "garbage" were separated into components by hand. The average results of the monthly determinations were used in connection with the figures in Table 2 to compute Table 3 which gives the results of the mechanical analyses. The graphic diagram, Fig. 1, brings out clearly the relative variations in the components of refuse from this district, and, as "garbage" is the primary cause of nuisance, it indicates that September will be the critical month when destroying mixed household wastes. February represents the opposite extreme of low "garbage" and high "coal and cinders." The large percentage of "fine ash" in winter suggests the advisability of removing this material, though the decision in this respect will depend upon practical experience in dealing with the refuse. As "garbage" carries nearly all the moisture in mixed refuse, a series of forty-one evaporative tests was made in order to determine its water content. Samples averaging 39 lb. were dried in a special water-jacketed evaporation pan, with the results indicated in Table 4.

TABLE 3.—COMPOSITION OF HOUSEHOLD REFUSE BY WEIGHT.

Month.	From Table 2.		From Mechanical Analysis.							
							Garbage.			
	Ashes and rubbish. Percentage.	Garbage. Percentage.	Fine ash. Percentage.	Clinker. Percentage.	Glass, metal, etc. Percentage.	Coal and cinders. Percentage.	Vegetable. Percentage.	Animal. Percentage.	Free water. Percentage.	Rubbish. Percentage.
1906.										
January	83.5	16.5	40.5	1.4	3.1	34.7	14.3	0.6	0.7	4.7
February	87.6	12.4	40.3	1.3	3.4	38.3	10.9	0.4	0.3	5.1
March	86.0	14.0	42.6	1.2	3.1	35.5	12.2	0.5	0.6	4.3
April	79.3	20.7	40.8	1.0	3.2	31.5	17.9	0.8	0.8	4.0
May	78.7	21.3	37.7	0.6	5.7	31.8	18.7	0.7	0.7	4.1
June	71.9	28.1	30.7	11.1	8.4	16.2	24.4	1.0	1.4	6.8
July	58.3	41.7	23.8	0.8	9.0	12.6	36.3	1.6	1.7	14.2
August	54.3	45.7	20.0	0.5	10.9	9.0	39.7	1.7	2.0	16.2
September	50.5	49.1	21.7	0.6	8.5	7.7	42.5	1.9	2.2	14.9
1905.										
October	60.1	39.9	29.0	3.5	6.6	15.2	30.9	3.1	1.5	10.2
November	71.4	28.6	31.8	0.7	5.2	30.8	22.6	1.8	1.0	6.1
December	76.6	23.4	34.4	0.9	3.1	34.6	19.6	1.1	0.8	5.5
Averages	73.3	26.7	34.7	1.8	4.8	26.7	22.6	1.2	1.1	7.1

TABLE 4.—EVAPORATIVE TESTS OF MOISTURE IN GARBAGE.

Date.	Weight of original sample, in pounds.	Weight of dried sample, in pounds.	Water evaporated, in pounds.	Water in original sample. Percentage	Hours drying.	Average water by months. Percentage.
Jan. 4, '06	46	10.09	35.91	78.2	88	75.9
Jan. 17, '06	50	13	37	74.0	104	
Feb. 8, '06	50	13.65	36.35	72.7	136	72.2
Feb. 26, '06	47	13.31	33.69	71.7	144	
March 23, '05	50	16	34	68.0	70	68.6
March 19, '06	49	15.09	33.91	69.2	96	
April 1, '05	40	12.5	27.5	68.7	70	69.6
April 7, '05	40	11	29	72.5	80	
April 2, '06	42	13.31	28.69	68.3	128	
April 20, '06	50	15.5	34.50	69.0	126	
May 17, '05	40	12	28	70.0	70	70.7
May 25, '05	39	12	27	69.2	60	
May 9, '06	47	13.5	33.5	71.3	104	
May 24, '06	50	14.0	36.0	72.0	130	
June 19, '05	39	8	31	79.4	60	70.6
June 9, '06	35	13.5	21.5	61.4	88	
June 26, '06	35	10.5	24.5	70.0	112	
July 2, '05	30	9.0	21	70.0	60	71.0
July 22, '05	39	11	28	71.8	70	
July 31, '05	39	9	30	76.9	60	
July 13, '06	46	13.5	32.5	70.6	104	
July 31, '06	36	12.5	23.5	65.3	80	
August 6, '05	39	9	30	76.9	60	74.7
August 11, '05	38	11	27	71.0	60	
August 27, '05	44	11	33	75.0	60	
August 14, '06	45	11	34	75.5	112	
Sept. 4, '05	38	10	28	73.6	70	73.1
Sept. 18, '05	45	13	32	71.1	50	
Sept. 20, '04	38	9.5	28.5	75.0	90	
Sept. 8, '06	45	11.5	33.5	74.4	60	
Sept. 17, '06	44	12.5	31.5	71.6	100	
Oct. 3, '05	26	8	18	69.2	50	67.4
Oct. 17, '05	33	12	21	63.6	50	
Oct. 26, '05	29	9	20	69.0	50	
Oct. 20, '04	47	15	32	68.1	100	
Nov. 6, '05	44	13	31	70.5	88	69.2
Nov. 16, '05	37	10.92	26.08	70.5	64	
Nov. 25, '05	36.5	12.31	24.19	66.3	104	
Dec. 11, '05	45	9.84	35.16	78.1	160	....
Average per cent. of water	....	....	....	71.4	....	....

FIG. 1.—VIEW SHOWING LOCATION OF DESTRUCTOR AT WREXHAM.

FIG. 3.—RATHMINES DESTRUCTOR, IRELAND. VIEW OF PLANT AND SURROUNDINGS FROM CLOCK TOWER OF TOWN HALL.

FIG. 2.—VIEW FROM WATER TOWER AT WREXHAM, SHOWING HOUSES NEAR DESTRUCTOR BUILDING.

FIG. 4.—MOSS SIDE DESTRUCTOR, MANCHESTER. HOUSES IN BACKGROUND WERE ERECTED AFTER DESTRUCTOR WAS PUT IN OPERATION.

IV.—Calorific Power of Refuse—Seasonal Variations.—Mixed refuse seemed to be an unpromising material for reduction to representative samples suitable for test in a calorimeter, but separate determinations of the components of refuse in conjunction with the mechanical analyses might be expected to serve the purpose of computing the calorific power of the refuse, within reasonable limits, for practical purposes.

Table 5 summarizes the principal features of a set of preliminary tests made at the Lederle Laboratories. The calorific determinations gave rather better results than might have been expected under the conditions of sampling then prevailing. An insufficient number of trials was made to show any seasonal variations in the heat values of the materials. Mixed refuse tests proved unsatisfactory, as might have been expected. A composite sample (No. 7488), by actual test and by computation, showed practical agreement, thus checking the assumption that the total calorific power of the refuse would equal the sum of the heat values of its constituents.

In February, 1907, there became available a very comprehensive series of calorific determinations, made during 1905 and 1906 at the laboratory of the Commissioners of Accounts, under the direction of Mr. Otto H. Klein, Chief Engineer, by B. F. Welton, Assoc. M. Am. Soc. C. E. Large amounts of the several components of refuse, from the mechanical analyses for each month, were reduced by quartering, moisture was evaporated from "garbage," and the different materials were roughly pulverized to representative samples at the West New Brighton crematory. Further preparation of samples for test in a Mahler bomb calorimeter was made at the laboratory. The method of procedure in these determinations differed from that of the preliminary determinations in the case of "rubbish," where the paper content was not pulped before being pulverized, also with "fine ash" and "clinker," which were burned with naphthaline to effect complete oxidation of the relatively small percentage of combustible matter.

The results of the various calorific determinations and proximate analyses by Mr. Welton, with the average seasonal variations of the different components, are shown in Table 6.

In this summary "coal and cinders" has a lower value in winter than during other seasons of the year, probably owing to the more complete combustion of fuel in cold weather; "garbage" shows no

4 368D	Rubbish.	February.	6 940	0.75	17.03	82.22	8 441	Original bulk sample reduced by quartering, paper portion pulped, coarsely ground with other rubbish, quartered, dried, pulverized, and again quartered down to test sample. Test results refer to original sample.
4 369B	"	February.	12 634	0.00	5.66	94.34	13 392	
4 665	"	March.	7 251	2.78	12.58	84.64	8 567	
6 280	"	May.	7 948	3.70	13.21	83.09	9 560	
7 357	"	July.	7 781	1.03	21.39	77.58	10 029	
7 358	"	July.	8 404	0.80	11.93	87.27	9 630	
7 440	"	August.	8 107	3.77	8.15	88.08	9 204	
	Average.	....	8 437	1.83	12.85	85.32	9 889	
4 368A	Fine ash.	February.	0 000	3.03	80.45	16.52	....	Same procedure as in "coal and cinders."
4 667	" "	February.	0 000	0.56	83.67	15.77	....	
	Average..................	....	....	1.79	82.06	16.14	....	
4 368C	Clinker.	February.	0 000	1.14	89.25	9.61	....	Same procedure as in "coal and cinders."
4 666	"	February.	0 000	0.61	90.34	9.05	....	
	Average..................	....	....	0.87	89.80	9.33	....	
4 668	Mixed refuse.	February.	3 903	0.00	46.89	53.11	7 349	Procedure as with components noted above. Total moisture not determined.
5 873	" "	April.	6 084	3.42	38.61	57.97	10 495	
6 918	" "	June.	5 700	0.31	58.95	40.74	13 991	
	Average..................	....	5 229	1.24	48.15	50.61	10 838	
7 438	Composite sample. Computed from separate tests.	See Laboratory Nos. 7 439, 7 440, 7 441.	8 254 8 452	1.18 2.28	21.35 21.14	77.47 76.58	10 654 11 097	Composed of: 53.4% Garbage, test No. 7 439. 19.6% Rubbish, " " 7 440. 27.0% Coal and cinders, test No. 7 441.

TABLE 5.—CALORIMETER TESTS. (PRELIMINARY SERIES.)

Laboratory No.	Material.	From collections in:	Test Results. Calorific power in B. t. u.	Test Results. Percentage of water	Test Results. Percentage of ash.	Test Results. Percentage of combustible.	Test Results. Calorific power of combustibles in B. t. u. Computed.	Notes.
		1905.						
4 868A	Coal and cinders.	February.	4 230	1.02	61.17	37.81	11 187	
4 663	" " "	February.	3 280	1.63	52.14	46.23	7 095	Original bulk sample reduced by quartering, pulverized, and again quartered down to test sample. Test results refer to original sample
5 074A	" " "	March	4 590	1.55	59.11	39.34	11 668	
5 495B	" " "	April	4 837	1.54	55.54	42.92	11 269	
6 288	" " "	May.	2 108	2.74	68.69	28.57	7 378	
7 359	" " "	July	7 710	0.99	39.33	59.68	12 920	
7 441	" " "	August.	7 554	2.01	42.42	55.57	13 591	
	Average		4 901	1.64	54.06	44.30	11 065	
4 869A	Garbage.	February.	5 320	4.47	32.44	63.09	8 432	O
4 664	"	February.	9 447	2.68	11.92	85.40	11 062	
5 074B	"	March.	7 874	0.00	12.19	87.81	8 967	
5 495A	"	April.	8 965	0.00	22.48	77.52	11 565	
6 281	"	May.	8 186	1.63	18.26	80.11	10 218	
7 358	"	July	8 878	0.00	13.04	86.96	10 209	
7 489	"	August.	9 034	1.84	15.16	83.00	10 884	bage. For moisture in original material, see Table 4.
	Average		8 243	1.52	17.93	80.55	10 233	

TABLE 6.—CALORIMETER TESTS AND

COAL AND CINDERS. (26 TESTS.)

Laboratory No.	Calorific Values. Per pound, original sample. B. t. u.	Per pound, dry sample. B. t. u.	Per pound, combustible. B. t. u.	From Collections Made: Season.	Month and year.	Proximate Analyses. Moisture. Percentage.	Volatile matter. Percentage.	Fixed carbon. Percentage.	Ash. Percentage.
921b	9 360	9 470	14 750	Spring...	Early March, 1906	1.14	4.02	59.44	35.40
922b	8 180	8 260	14 290		Late " 1906	0.97	2.83	54.40	41.80
928b	8 630	8 765	15 010		Early April, 1906	1.52	4.36	53.14	40.98
929b	9 360	9 505	14 270		Late " 1906	1.50	3.40	62.20	32.90
936b	7 840	7 932	14 340		Early May, 1906	1.08	2.04	52.66	44.22
946b	9 645	9 850	14 400		Late " 1906	2.02	4.88	62.13	30.97
	8 836	8 957	14 504	Average, spring		1.37	3.59	57.33	37.71
952b	9 497	9 590	15 270	Summer.	Early June, 1906	2.03	4.90	56.60	36.47
971b	9 930	10 110	13 850		Late " 1906	1.78	5.09	66.67	26.46
883b	7 865	8 018	14 500		July, 1905	1.90	14.70	39.60	43.80
975b	7 150	7 250	14 020		Early " 1906	1.37	2.88	48.13	47.62
976b	9 740	9 967	14 050		Late " 1906	2.28	2.91	66.43	28.43
994b	9 570	9 770	14 450		Early August, 1906	2.06	6.98	59.10	31.86
995b	7 080	7 135	13 860		Late " 1906	0.75	3.91	47.16	48.18
	8 690	8 843	14 312	Average, summer		1.73	5.91	54.81	37.55
858b	8 561	8 813	12 800	Autumn.	September, 1905	2.24	7.78	59.16	30.82
998b	10 865	11 135	14 420		Early Sept., 1906	2.32	4.02	71.38	22.28
1 011b	10 583	10 840	14 980		Late " 1906	2.28	4.05	66.57	27.10
862b	7 805	7 920	13 580		Early Oct., 1905	1.42	1.12	56.36	41.10
875b	8 445	8 540	15 065		Late " 1905	1.04	2.02	54.04	42.90
882b	8 490	8 580	15 010		Early Nov., 1905	1.08	1.85	54.73	42.39
887b	7 378	7 440	15 225		Late " 1905	0.82	2.13	46.33	50.72
	8 876	9 020	14 397	Average, autumn		1.59	3.28	58.37	36.76
894b	7 270	7 320	14 460	Winter...	Early Dec., 1905	0.62	2.21	48.07	49.10
895b	8 210	8 265	13 810		Late " 1905	0.65	1.59	57.84	39.92
899b	6 940	6 980	13 450		Early Jan., 1906	0.58	1.51	50.09	47.82
900b	6 060	6 080	13 310		Late " 1906	0.27	2.12	43.44	54.17
901b	6 910	6 935	14 350		Early Feb., 1906	0.37	2.05	46.10	51.48
903b	6 935	6 988	13 880		Late " 1906	0.78	1.66	48.28	49.28
	7 054	7 091	13 878	Average, winter		0.54	1.86	48.97	48.03
	8 396	8 510	14 296	Average, all tests		1.34	3.73	55.00	39.93

Proximate Analyses (Welton).

Garbage. (25 Tests.)

Laboratory No.	Calorific Values. Per pound, original sample. B. t. u.	Per pound, dry sample. B. t. u.	Per pound, combustible. B. t. u.	From Collections Made: Season.	Month and year.	Proximate Analyses. Moisture. Percentage.	Volatile matter. Percentage.	Fixed carbon. Percentage.	Ash. Percentage.
921a	2 585	8 633	10 490	Spring...	March, 1906	70.68	19.76	4.40	5.21
923a	2 690	8 910	9 970		Early April, 1906	69.80	22.60	4.40	3.20
928a	2 459	8 500	10 365		Late " 1906	71.08	19.21	4.50	5.21
929a	2 195	8 305	9 492		Early May, 1906	73.24	18.57	4.55	3.64
936a	1 779	7 025	11 500		Late " 1906	74.69	11.23	4.23	9.85
	2 331	8 294	10 273	Average, spring..........		71.89	18.27	4.42	5.42
946a	3 029	8 510	10 700	Summer.	Early June, 1906	64.43	20.01	8.29	7.27
971a	2 238	8 235	10 440		Late " 1906	72.83	17.19	4.24	5.74
975a	2 839	8 560	10 550		Early July, 1906	73.43	18.11	3.97	4.49
976a	2 507	7 980	9 400		Late " 1906	68.59	21.38	5.30	4.73
994a	1 706	7 665	9 280		Early August, 1906	77.74	14.58	3.80	3.88
995a	2 076	8 950	10 460		Late " 1906	76.30	16.82	3.53	3.35
833a	1 758	8 935	10 770		July, 1905	80.50	14.68	1.59	3.23
	2 334	8 421	10 220	Average, summer.........		73.47	17.47	4.39	4.67
858a	2 190	8 533	10 550	Autumn.	September, 1905	74.31	16.75	4.03	4.91
998a	2 063	8 720	10 520		Early Sept., 1906	76.33	16.02	3.59	4.06
1 011a	1 652	7 720	9 450		Late " 1906	73.60	18.97	3.52	3.91
862a	2 189	8 228	10 120		Early Oct., 1905	73.40	11.62	10.00	4.98
875a	3 050	8 805	10 720		Late " 1905	65.35	21.18	7.27	6.20
882a	2 354	8 003	9 820		Early Nov., 1905	70.59	18.87	5.12	5.42
887a	1 719	6 065	10 275		Late " 1905	71.66	11.17	5.56	11.61
	2 174	8 022	10 240	Average, autumn.........		72.89	15.65	5.58	5.87
894a	2 580	7 955	10 160	Winter...	Early Dec., 1905	67.56	19.28	6.12	7.04
895a	1 807	8 750	10 390		Late " 1905	79.35	14.21	3.18	3.26
899a	2 009	9 570	11 180		Early Jan., 1906	79.01	14.28	3.67	3.04
900a	2 008	8 010	10 310		Late " 1906	74.93	14.84	4.63	5.60
901a	2 729	10 330	11 545		Early Feb., 1906	73.60	19.84	3.78	2.78
903a	2 192	8 106	10 375		Late " 1906	72.95	16.54	4.58	5.93
	2 221	8 734	10 668	Average, winter..........		74.57	16.50	4.32	4.61
	2 238	8 351	10 338	Average, all tests.........		73.26	16.89	4.71	5.14

TABLE 6.—CALORIMETER TESTS AND PROX-

RUBBISH. (26 TESTS.)

Laboratory No.	Caloric Values. Per pound, original sample. B. t. u.	Per pound, dry sample. B. t. u.	Per pound, combustible. B. t. u.	From Collections Made: Season.	Month and year.		Proximate Analyses. Moisture. Percentage.	Volatile matter. Percentage.	Fixed carbon. Percentage.	Ash. Percentage.
981*c*	7 070	7 360	8 385	Spring...	Early March,	1906	3.95	69.04	15.31	11.70
921*c*	6 999	7 238	9 330		Late "	1906	3.21	62.77	12.23	21.79
922*c*	6 895	6 555	8 692		Early April,	1906	2.46	60.94	12.64	23.96
928*c*	6 490	6 821	8 220		Late "	1906	4.74	64.49	14.52	16.25
929*c*	6 810	7 210	9 220		Early May,	1906	5.55	56.12	17.72	20.61
936*c*	7 220	7 690	8 370		Late "	1906	6.08	74.98	11.82	7.62
	6 831	7 140	8 682	Average, spring...........			4.33	64.72	13.96	16.99
946*c*	6 088	6 920	8 810	Summer.	Early June,	1906	7.13	52.60	16.52	23.75
971*c*	6 895	7 485	8 070		Late "	1906	7.90	70.46	15.06	6.58
975*c*	7 040	7 748	8 880		Early July,	1906	9.14	66.31	13.00	11.55
976*c*	7 028	7 463	7 950		Late "	1906	5.83	73.78	14.64	5.75
833*c*	6 308	6 870	7 230		July,	1905	8.20	75.60	11.70	4.50
994*c*	6 717	7 480	8 375		Early August,	1906	10.22	64.94	15.27	9.57
995*c*	6 780	7 330	8 175		Late "	1906	7.55	68.44	14.50	9.51
	6 694	7 275	8 179	Average, summer			7.99	67.45	14.39	10.17
858*c*	6 720	7 183	9 120	Autumn.	September.	1905	6.45	54.30	19.35	19.90
998*c*	5 360	5 687	7 880		Early Sept.,	1906	5.74	51.84	17.20	25.22
1 011*c*	6 570	7 062	8 430		Late "	1906	6.97	63.06	14.91	15.06
862*c*	5 567	5 808	8 950		Early Oct.,	1905	4.17	49.86	15.00	30.97
875*c*	7 130	7 575	8 170		Late "	1905	5.84	69.94	17.44	6.78
882*c*	7 742	8 343	8 910		Early Nov.,	1905	7.16	72.68	14.26	5.90
887*c*	7 455	7 873	8 965		Late "	1905	5.34	67.81	15.37	11.48
	6 649	7 069	8 570	Average, autumn....			5.95	61.86	16.22	16.47
894*c*	7 012	7 310	8 145	Winter...	Early Dec.,	1905	4.04	71.06	15.00	9.90
895*c*	6 870	7 225	8 370		Late "	1905	4.90	69.07	13.06	12.97
899*c*	8 325	8 740	9 520		Early Jan.,	1906	4.72	71.93	15.54	7.81
900*c*	6 250	6 510	7 985		Late "	1906	3.96	65.91	12.40	17.73
901*c*	7 280	7 580	8 750		Early Feb.,	1906	3.88	70.50	12.75	12.87
903*c*	7 525	7 933	8 950		Late "	1906	5.10	68.90	15.20	10.80
	7 210	7 545	8 630	Average, winter...........			4.44	69.56	13.99	12.01
	6 832	7 251	8 508	Average, all tests..........			5.78	65.66	14.69	13.87

IMATE ANALYSES (WELTON).—(*Continued*).

OTHER TESTS.

Laboratory No.	Caloriric Values. Per pound, original sample. B. t. u.	Per pound, dry sample. B. t. u.	Per pound, combustible. B. t. u.	Material, etc.	Proximate Analyses. Moisture, percentage.	Volatile matter, percentage.	Fixed carbon, percentage.	Ash, percentage.
923*f*	2 846	2 880	13 300	Fine ash. Screened from collections. 1905–1906.	1.20	4.02	17.38	77.40
1 031	1 578	1 583	10 038	Clinker. From collections 1905–1906.	0.32	0.73	14.99	83.96
892*e*	3 998	3 998	14 117	Ash. From practical tests in burning mixed refuse, December, 1905.	0.00	2.86	25.46	71.68
892*d*	900	900	8 730	Clinker. From practical tests in burning mixed refuse, December, 1905.	0.00	0.00	10.31	89.69
See 833*a* 833*b* 833*c*				Composite sample. Garbage...........53.4% by weight Coal and cinders. 27.0% " " Rubbish.......... 19.6% " "				
833*d*	4 364	7 952	10 659	By test.	45.12	40.94		13.94
	4 394	7 823	10 618	By calculation. From Tests 833*a*, 833*b* and 833*c*.	45.11	26.63	13.83	14.43

appreciable seasonal variation, and "rubbish" has a higher power in winter than in spring, summer, or autumn. The test of a single average sample of "fine ash" and of "clinker" leaves the question of seasonal variations undetermined with regard to these materials. On the whole, the seasonal differences are not marked, except in the case of "coal and cinders." The columns giving the heat units per pound of dry sample show the variations in the mechanical analyses and the bulk sampling, while the calorific power per pound of combustible compares the character of the materials tested, and was used as an additional check in the calorimeter determinations. The results of the tests shown in Table 6 were much more consistent than was ever hoped for.

Based on the composition of refuse (Table 3) and the final calorific tests (Table 6), the heat value per pound of refuse for different periods has been deduced, as shown in Table 7.

TABLE 7.—Calorific Value per Pound of Refuse for Different Periods.

Period.	Calorific power of combustible, B. t. u.	Moisture, per cent.	Ash, per cent.	Combustible, per cent.	Remarks.
Spring......	4 747	14.03	50.06	35.91	Computed results based on average figures for corresponding periods in Tables 3 and 6, except that average calorific values for summer components were used in arriving at September results.
Summer....	3 477	28.86	39.74	31.40	
Autumn.....	3 833	27.74	39.74	32.52	
Winter......	4 358	13.11	52.72	34.17	
Year........	4 274	19.74	46.03	34.23	
September..	3 265	35.83	33.69	30.48	

Compared with the results computed from the preliminary calorific tests (Table 5), the values in Table 7 will be found to be considerably higher, due to including the combustible power of the "fine ash" and the greater heat value of "coal and cinders."

September has the minimum calorific power and the maximum amount of moisture, thus becoming the most trying month in burning mixed refuse.

V.—Practical Tests in Burning Refuse.—While other examinations were progressing, practical tests in burning refuse were conducted at

PLATE XCIX.
PAPERS, AM. SOC. C. E.
NOVEMBER, 1907.
FETHERSTON ON
REFUSE DESTRUCTION.

FIG. 1.—BROMLEY DESTRUCTOR. HOUSES TO THE RIGHT.

FIG. 2.—BROMLEY DESTRUCTOR. RESIDENCES NEARBY.—IN PLAIN SIGHT OF PLANT.

FIG. 3.—SHOREDITCH DESTRUCTOR IS IN REAR OF CHAPEL, WITH BUILDINGS ON ALL SIDES.

FIG. 4.—ANOTHER VIEW AT SHOREDITCH. THE DESTRUCTOR IS AT THE RIGHT OF THE CHIMNEY.

the West New Brighton crematory. The coal grate of the Dixon garbage furnace (12 sq. ft. in area) was used for burning the materials. Air at atmospheric temperature was forced into the ash-pit by a Sturtevant fan driven by an electric motor. Paper and wood, reduced to a glowing mass on the grate, were used to start the fire, except where otherwise noted in Table 8, which summarizes the results of forty-two trials, with other experimental data. In spite of such adverse conditions as cold air blast, cold furnace walls, leakage of air through warped doors, and high percentage of moisture, with small amount of combustible in some trials, all the tests except one were successful in destroying mixed household refuse, though unburned particles were at times found in the residue.

The general deductions from these rough practical tests may be summed up as follows:

1.—Household refuse, as collected in this district, when burned in a properly designed furnace, will be self-combustible, under ordinary conditions, showing higher calorific power in winter than in summer. Screened refuse will give better results in burning than unscreened.

2.—About 80 lb. of refuse per sq. ft. of grate could be burned before it became necessary to remove the clinker.

3.—The process may be made continuous by retaining the heated coals from the top portion of the fire and removing the mass clinker. Coal may be required to heat the furnace walls if the operation of the plant is not made continuous.

4.—The rate of burning will be higher in summer than in winter.

5.—The percentage of clinker will also vary with the seasons, being high in winter and low in summer. The total residue was not determined, as a large portion of the fine ash was carried over by the air blast and could not be recovered.

6.—The heat lost by the removal of hot clinker varied from 300 to 500 B. t. u. per lb. of clinker.

7.—Street sweepings from this locality could not be burned with household refuse, except when mixed in small proportions.

VI.—Power from Refuse—Temperatures.—In spite of the fact that British engineers have had years of experience with refuse destructors, the writer has been able to find only one scientific test which would assist in determining the actual power to be obtained from refuse of known calorific value. Mr. C. E. Stromeyer (in January,

TABLE 8.—PRACTICAL TESTS

Test No.	Date. 1905.	Kind of material burned.	Amount of refuse, in pounds.	Time burning, in minutes.	Rate of burning, per square foot of grate, per hour.	Temperature or appearance of fire.	Air pressure in ash-pit. Inches of water.	Chimney smoke.
1	Apr. 16.	Composite sample "*A*".....	500	51	49	Short orange to yellow flame.	....	Hardly visible except when feeding.
2	"	Composite sample "*B*".....	500	40	62½	" " "	....	" " "
3	"	Mixed refuse as collected..	1 000	20	.....	Smoke. No flame. Fire smothered.	....	....
4	"	" "	1 000	60	83.3	Short yellow to white flame.	....	Hardly visible except when feeding.
5	Apr. 23.	" "	1 600	90	88.8	Short yellow to white flame, 800 to 1 200° fahr.	1½	Dense white at start. Hardly visible later.
6	Apr. 30.	" "	470	37	63.5	800-1 200° fahr. Melted lead, zinc and aluminum.	¾	Light white smoke.
7	"	" "	470	50	....	Fire failed to spread.	¾	....
8	May 28.	" "	500	37	67.5	800° fahr.	¾	Light white smoke.
9	"	Composite sample "*C*".....	1 000	90	55.5	1 200° fahr.	¾	Dense to light white smoke.
10	June 25.	Mixed refuse as collected..	1 100	90	61	Yellow to white flame.	1½	" " "
11	July 9.	" "	......	....	.....	....	....	Murky smoke at start, then light white.
11		Material in rain overnight. Contained 37.5% moisture.	......	....	.....	....	....	....
12	July 23.	Mixed refuse as collected..	950	60	79	800°-1 200° fahr.	1	Light white to hardly visible smoke.
13	Aug. 6.	Composite sample "*D*".....	500	....	.....	Clear hot fire..	¾	Light white smoke.
14	"	" " "*E*".....	300	....	.....	Fire smothered.	1½	" " "
15	Aug. 20.	Mixed refuse as collected..	1 500	90	83.3	Clear hot fire.	1½	Murky at start. Hardly visible later.
16	Sept. 10.	" "	1 431	....	.....	Poor fire. Low temperature.	1	Murky to white dense smoke.
17	Sept. 17.	" "	1 126	60	94	Low temperature.	1¼	Murky to light white.
18	Sept. 24.	" "	986	60	82	1 000° fahr.	¾	Dense to light white smoke.
19	Oct. 1.	" "	1 547	90	86	Above 1 200° fahr.		Light white to hardly visible.

IN BURNING REFUSE.

Residue (excluding dust). Clinker. Weight, in pounds.	Clinker. Percentage.	Ashes. Weight, in pounds.	Ashes. Percentage.	Total residue. Weight, in pounds.	Total residue. Percentage.	Character of clinker.	Notes.
179	35.8	......	......	......	......	Vitreous.........	Refuse ignited on bed of hot coals. Two charges of 250 lb. each. Burned freely.
231	46.2	......	......	......	......	"	Hot furnace walls. Material burned freely.
......	......	......	......	......	......	....	Refuse not properly ignited. Too much air from blast.
301	30.1	......	......	......	......	Vitreous. Well burned.	Same material as in 3. Started properly. Burned freely.
379	23.7	107	6.7	486	30.4	" "	Material burned freely.
137	29.2	......	......	......	......	" "	Material burned freely. One-half of grate clinkered, other half of clinker spread to start Test 7.
......	......	......	......	......	......	....	Clinker from former test failed to ignite fresh refuse.
140	28	43	8	183	36.6	Vitreous..........	Material burned freely.
329	33	87	9	416	42	Dense vitreous clinker.	Hot furnace walls from Test 8. Material burned freely. Clinker very hard and dense.
378	34.4	......	......	......	......	Vitreous.	Test to determine amount of refuse that could be burned before clinkering became necessary. Result—about 80 lb. per sq. ft. of grate.
......	......	......	......	......	......	....	Test to determine amount of kindlings necessary to ignite the refuse properly. First—20 lb. of paper was tried with partial success.
......	......	......	......	......	......	....	Second—11 lb. paper, 59½ lb. wood used. Material burned freely. Much smoke in furnace room during both trials—due to moisture in refuse.
269	28.3	......	......	......	......	Vitreous	Refuse in rain over-night. Contained large quantity of garbage, grass, weeds and paper. Very little ashes.
......	......	......	......	......	......	....	Burned freely. Clinker apparently very dense.
......	......	......	......	......	......	....	Charged on Test 14 when "*D*" was burned down to glowing mass. Fire smothered by sweepings in "*E.*"
477	31.8	136	9.0	613	40.8	Vitreous	Refuse mostly green vegetable matter with small amount of ashes and rubbish.
......	......	......	......	......	......	No clinker formed.	Refuse contained much wet sawdust, decayed fish and vegetables from stores. Moisture 56.5%. Not completely burned. Very smoky in furnace room.
317	28.1	......	......	......	......	Fair. Not dense. Material not all burned.	Large amount of yard sweepings in refuse, very little combustible. Too much air from blower.
264	26.8	......	......	......	......	Small amount of clinker. Mostly ashes on grate.	Large quantity garbage, small amount of ashes and rubbish. Less air than in 17 with better results. Not much clinker formed.
379	24.5	125	8	504	32.5	Vitreous. Well burned.	Material from residential section. Large amount of ashes.

TABLE 8—PRACTICAL TESTS

Test No.	Date. 1905.	Kind of material burned.	Amount of refuse, in pounds.	Time burning, in minutes.	Rate of burning, per square foot of grate per hour.	Temperature or appearance of fire.	Air pressure in ash-pit. Inches of water.	Chimney smoke.
20	Oct. 15.	Mixed refuse as collected..	1 495	80	98	Above 1 200° fahr.	1½	Light white to hardly visible.
21	Oct. 29.	" "	1 254	80	78.4	" " "	1½	" " "
22	Nov. 12.	" "	1 148	120	47.8	" " "	1	" " "
23	Nov. 26.	" "	1 159	90	64.4	" " "	1	" " "
24	Dec. 10.	" "	1 559	125	62.4	" " "	1½	Murky at start. Hardly visible later.
	1906.							
25	Jan. 7.	" "	1 200	90	66.6	Temp. low.	Gauge broken.	Light white smoke.
26	Jan. 21.	" "	1 128	60	94	Temp. low.	"	Murky at start. Hardly visible later.
27	Feb. 4.	" "	1 120	70	80	Above 1 000° fahr.	"	Light white at start. Not visible later.
28	Feb. 18.	" "	1 180	90	74	Above 1 200° fahr.	"	Murky at start. Hardly visible later.
29	Mar. 11.	" "	1 500	90	83.3	Temp. by pyrometer 1 600° fahr.	"	Light white at start. Hardly visible later.
30	Mar. 25.	" "	1 000	90	55.5	Combustion chamber temp. by pyrometer 1 100° fahr.	"	Light white to hardly visible.
31	Apr. 8.	" "	1 335	90	74.2	Highest temp. 1 420° fahr.	"	White at start. Not visible later.
32	Apr. 22.	" "	1 200	75	80	Highest temp. 1 400° fahr.	"	Light white at start. Not visible later.
33	May 6.	" "	1 200	75	80	Highest temp. 1 350° fahr.	"	Light white at start. Hardly visible later.
34	May 20.	" "	1 200	60	100	Highest temp. 1 150° fahr.	"	Dense white at start.
35	June 3.	" "	1 100	75	73.3	Highest temp. 1 320° fahr.	"	Light white smoke.
36	June 17.	" "	1 280	70	91.4	Highest temp. 1 400° fahr.	"	Light white at start. Not visible later.
37	July 8.	" "	1 880	....	.....	Highest temp. 1 400° fahr.	"	Light white at start.
38	July 22.	" "	1 400	....	.....	Highest temp. 1 300° fahr	"	Heavy white at start.
39	Aug. 5.	" "	1 250	115	.....	Highest temp. 1 400° fahr.	"	Dense white at start. Light white later.
40	Aug. 19	"	1 100	60	92	Temp. high. 1 700° fahr.	"	Light white smoke.
41	Sept. 2.	" "	1 030	60	86	Highest temp. 1 350° fahr.	"	Dense white at start.
42	Sept. 23.	" "	1 200	75	80	Highest temp. 1 400° fahr.	"	Dense white at start. Hardly visible later.

IN BURNING REFUSE—(*Continued.*)

Residue (excluding dust). Clinker. Weight, in pounds.	Clinker. Percentage.	Ashes. Weight, in pounds.	Ashes. Percentage.	Total residue. Weight, in pounds.	Total residue. Percentage.	Character of clinker.	Notes.
326	21.8	90	6	416	27.8	Vitreous. Well burned.	Large quantity of green vegetables and decayed fish. Burned rapidly.
327	26	73	6	400	32	" " "	Large proportion of fine ash and vegetables, very little rubbish.
432	37.6	82	7.2	514	44.8	" " "	Large amount of garbage and fine ash.
334	28.8	87	7.5	421	36.3	" " "	Large proportion of fine ash, small amount of coal and cinders.
564	36.2	181	11.6	745	47.8	" " "	About half of refuse burned down, mass clinkers then removed and other half of refuse charged on coals of first fire. Material burned freely in both cases.
......	......	......	......	......	......	Poor. No mass clinker. Mostly ashes.	Poor quality of material. Large amount of incombustible. Residue not completely burned.
......	......	......	......	......	......	Rather poor.....	Material poor in quality. Purpose of test—to determine the amount of waste heat in clinker. 511 B. t. u. per lb.
......	......	......	......	......	......	Hard. Well burned.	Material of fair quality. Waste heat in clinker, tested, gave 315 B. t. u. per lb.
367.5	31.1	141	12.0	508.5	43.1	Hard. Well burned.	Refuse of fair quality. Waste heat from residue on grate gave 488 B. t. u. per lb.
518	34.5	132	8.8	650	43.3	Hard. Well burned.	Bristol electric pyrometer used for taking temperature readings. Combustion chamber 1 600° F. Chimney 1 000°
478	47.8	80	8.0	558	55.8	Hard. Well burned.	Fire not well started. Excess of air.
421	31.5	88	6.6	509	38.1	Hard. Well burned.	Material wet. In rain over-night. Furnace room smoky.
290	24.2	161	13.4	451	37.6	Hard. Well burned.	Refuse dry, large quantity of fine ash.
293	24.4	100	8.3	393	32.7	Hard. Well burned.	Refuse damp. Burned rapidly.
302	25.2	63	5.2	365	30.4	Poor. Little mass clinker.	Fire poorly started. Much smoke from furnace. Excess of air.
219	19.9	115	10.5	334	30.4	Fair	Excess of air.
308	24.1	115	9.0	423	33.1	Hard. Well burned.	Material burned rapidly. Probable excess of air.
.....	......	......	......	......	......	....	Electric motor broke down. Test not finished. Material of very poor quality—very wet.
.....	......	......	......	......	......	....	Test not finished. Belt to fan broke. Material in rain over-night.
.....	......	......	......	......	......	....	Material practically all garbage, contained 40% water. Required coal to burn it properly.
259	23.5	108	9.8	367	33.3	Well burned. Not much mass clinker.	Material burned freely. High tem. Clinker cooled in air dropped 1 360° fahr. in 40 min.
212	20.6	57	5.5	269	26.1	Not much lump clinker.	Some unburned corncobs in ashes. Clinker cooled by fan blast dropped 1 280° fahr. in 20 min. Excess air.
272	22.7	73	6.0	345	28.7	Not much lump clinker. Not completely burned.	Unburned corncobs and wood. Excess of air. Test to determine temp. to which air could be heated by hot clinker. See Note 42.

TABLE 8—PRACTICAL TESTS IN BURNING REFUSE.—(*Continued.*)

Composition of Refuse Burned.

Test No. 1. Composite "A."

Coal and cinders	208 lb.	= 41.6%
Rubbish	31½ "	= 6.3 "
Clinker	45½ "	= 9.1 "
Garbage	194 "	= 38.8 "
Glass, metals, etc	21 "	= 4.2 "
Totals	500 "	100 "

Test No. 2. Composite "B."

Coal and cinders	145 lb.	29%
Rubbish	20 "	4 "
Clinker	35 "	7 "
Garbage	265 "	53 "
Glass, metals, etc	35 "	7 "
Totals	500 "	100 "

Tests 3 and 4. Sample.

Coal and cinders	60 lb.	37.5%
Garbage	13 "	8.1 "
Rubbish	4 "	2.5 "
Glass, metals, etc	3 "	1.9 "
Clinker	7 "	4.4 "
Fine ash	73 "	45.6 "
Totals	160 "	100 "

Test 5. Sample.

Coal and cinders	68 lb.	46.3%
Garbage	17 "	11.5 "
Rubbish	11.5 "	7.8 "
Glass, metals, etc	4.5 "	3.0 "
Clinker	5 "	3.4 "
Fine ash	41 "	28.0 "
Totals	147 "	100 "

Moisture test, 112 hr. drying.

Weight, original sample	56 lb.
" dried "	45 "
Water evaporated	11 "

Moisture, 19.6%.

Tests 6 and 7. Sample.

Coal and cinders	11.5 lb.	27.0%
Garbage	10 "	23.6 "
Rubbish	2 "	4.7 "
Glass, metals, etc	1.5 "	3.5 "
Clinker	0.5 "	1.2 "
Fine ash	17 "	40.0 "
Totals	42.5 "	100 "

Moisture test, 112 hr. drying.

Weight, original sample	42.5 lb.
" dried "	33.5 "
Water evaporated	9.0 "

Moisture, 21%.

Test 8. Sample.

Fine ash	18 lb.	31%
Coal and cinders	13 "	22 "
Rubbish	6 "	10 "
Garbage	16 "	28 "
Glass, metals, etc	5 "	9 "
Totals	58 "	100 "

Moisture test, 112 hr. drying.

Weight, original sample	42 lb.
" dried "	35 "
Water evaporated	7 "

Moisture, 16.6%.

Test 9. Composite "C."

Coal and cinders	243 lb.	24.3%
Clinker	81 "	8.1 "
Glass, metals, etc	19 "	1.9 "
Garbage	480 "	48.0 "
Rubbish	177 "	17.7 "
Totals	1 000 "	100 "

Test 10. Sample.

Coal and cinders	27 lb.	22.7%
Rubbish	9 "	7.6 "
Glass, metals, etc	6 "	5.0 "
Garbage	23 "	19.3 "
Clinker	4 "	3.4 "
Fine ash	50 "	42.0 "
Totals	119 "	100 "

Sample of material from Test 10 showed 5 700 B. t. u. on dry refuse. (See Table 5, Lab. No. 6 918.)

Test 11. Moisture Test.
96 hr. drying.

Weight, original sample	32 lb.
" dried "	20 "
Water evaporated	12 "

Moisture, 37.5%.

TABLE 8—PRACTICAL TESTS IN BURNING REFUSE.—(*Continued.*)

Composition of Refuse Burned.

Test 14. Composite "E."

Coal and cinders	60.75 lb.	12.1%
Clinker	20.25 "	4.1 "
Glass, metals, etc	4.75 "	1.0 "
Garbage	120.00 "	24.0 "
Rubbish	44.25 "	8.8 "
Street sweepings	250.00 "	50.0 "
Totals	500 "	100 "

Test 24. Sample.

Fine ash	52.0 lb.	45.8%
Clinker	7.0 "	6.2 "
Glass, metals, etc	4.5 "	3.9 "
Coal and cinders	33.5 "	29.5 "
Garbage	13.0 "	11.5 "
Rubbish	3.5 "	3.1 "
Totals	113.5 "	100 "

Test 32. Moisture.

Weight, original sample	23.5 lb.
" dried "	21.0 "
Water	2.5 "

Moisture, 10.7%.

Test 35. Moisture.

Original sample	35 lb.
Dried "	29 "
Water	6 "

Moisture, 17.2%.

Test 36. Moisture.

Original sample	35 lb.
Dried "	28 "
Water	7 "

Moisture, 20%.

Test 39. Moisture.

Original sample	30 lb.
Dried "	18 "
Water	12 "

Moisture, 40%.

Test 41. Estimated composition.

Ashes	50% by weight.
Garbage	30 " " "
Rubbish	15 " " "
Tins, etc	5 " " "

Note.—35 lb. hot clinker was cooled from 1 700° fahr. to 420° fahr. (1 280° fahr.) by air blast in 20 min.

Test 13. Composite "D."

Coal and cinders	121.5 lb.	24.3%
Clinker	40.5 "	8.1 "
Glass, metals, etc	9.5 "	1.9 "
Garbage	240.0 "	48.0 "
Rubbish	88.5 "	17.7 "
Totals	500 "	100 "

Test 16. Moisture Test.
96 hr. drying.

Weight, original sample	23 lb.
" dried "	10 "
Water evaporated	13 "

Moisture, 56.5%.

Test 34. Sample.

Fine ash	23 lb.	29.1%
Coal and cinders	28 "	35.4 "
Clinker	4 "	5.1 "
Rubbish	8 "	10.1 "
Garbage	16 "	20.3 "
	79 "	100 "

Moisture test.

Original sample	32 lb.
Dried "	26 "
Water	6 "

Moisture, 19%.

Test 38. Moisture.

Original sample	35 lb.
Dried "	28 "
Water	7 "

Moisture, 20%.

Test 40. Estimated composition.

Ashes	60% by weight.
Garbage	30 " " "
Rubbish	8 " " "
Tins, etc	2 " " "

Note.—Hot clinker from grate cooled 1 300° fahr. in air, in 40 min.

Test 42. Estimated composition.

Garbage	60% by weight.
Ashes	30 " " "
Rubbish	7 " " "
Tins, etc	3 " " "

Note.—Air at 84° fahr. was heated to 423° in passing through hot clinker. After 5 min. the air forced through the hot clinker by the fan dropped from 423° to 270° fahr. 74 lb. of clinker with large volume of air was used.

TABLE 8.—PRACTICAL TESTS IN BURNING REFUSE.—(*Continued*).

Summary Showing Residue from Tests.

Season.	Refuse burned, in pounds	Time of burning, in minutes.	Rate of burning, per square foot of grate per hour.	RESIDUE.			
				Clinker.		Ashes from Ash-pit.	
				Pounds.	Percent.	Pounds.	Percent.
Spring........	9 585	607	78.5	2 821	29.6	774	8.1
Summer......	4 960	295	84.5	1 263	25.4	474	9.5
Autumn......	8 833	595	74.0	2 282	25.8	587	6.7
Winter	2 739	215	68.5	932	34.0	322	11.7
Year.........	26 087	1 712	76.0	7 298	28.0	2 157	8.3

1903), by continuous gas analysis, made an economic test and worked out a heat balance for the destructor at Nelson, England. Guided by some of the results of this test, and based upon the experience gained and experiments made in the burning of local mixed refuse, the writer has arranged the approximate heat balance shown in Table 9.

Column 12 in Table 9 answers the question (approximately and theoretically) as to the probable evaporative power of local refuse when burned in an up-to-date destructor, and Column 13 shows the estimated temperature of the combustion chamber under the assumed conditions of burning.

The calculated evaporative power of local refuse is generally higher, and shows a greater seasonal variation than that indicated by published tests with British refuse. September remains the critical month in destroying the material.

Summarizing the results of examinations, tests, and experiments with mixed household refuse from the district considered, the following conclusions are derived:

1.—Average local refuse differs mainly from what is known concerning average English refuse in the higher percentage of incombustible matter and the lower percentage of water. The average results to be expected in power production are surprisingly high, and the seasonal variations are greater with local refuse than with British refuse.

2.—Under expert management, with a properly designed furnace, the process can be carried out in settled communities without nuisance.

TABLE 9.—APPROXIMATE HEAT BALANCE PER POUND OF REFUSE. ESTIMATED TEMPERATURES.

(1)	(2)	Losses due to:							(10)	(11)	(12)	(13)
		(3)	(4)	(5)	(6)	(7)	(8)	(9)				
Period.	Calorific power of refuse, in B. t. u.	Moisture, in B. t. u.	Heat in dry chimney gases, in B. t. u.	Unburned carbon in clinker, in B t. u.	Unburned carbon in ashes, in B. t. u.	Heat in clinker, in B. t. u.	Forced draft, in B. t. u.	Radiation, etc., in B. t. u.	Total losses, in B. t. u.	Net useful heat to boiler, in B. t. u.	Equivalent evaporation, from and at 212° fahr. (useful steam), pounds of water.	Estimated temperature of combustion chamber, in degrees Fahrenheit.
Spring.............	4 747	184	465	266	334	55	121	949	2 364	2 383	2.46	2 370
Summer...........	3 477	373	407	229	380	38	106	695	2 228	1 249	1.29	1 710
Autumn...........	3 833	363	421	232	268	44	110	767	2 205	1 628	1.68	1 950
Winter	4 358	174	443	306	468	63	115	872	2 441	1 917	1.98	2 140
Year...............	4 274	259	444	252	332	54	116	855	2 312	1 962	2.03	2 150
September	3 265	465	395	229	330	54	108	653	2 279	986	1.02	1 550

3.—The average local residue will be greater than the average English residue mainly because of the high percentage of fine ash which will to some extent be carried away from the fire-grate by the forced draft.

4.—As compared with the local cost of burning garbage and caring for "ash and rubbish" dumps, the cost of the destruction of mixed refuse will probably be higher, though a proper utilization of the steam generated and the clinker resulting may offset this increase in cost, while a rearrangement of the refuse collection system may tend further to make the cost of the methods comparable.

5.—For the particular conditions herein considered, mixed-refuse destruction appears to offer the best solution of the problem.

Part II.

Pending the acquisition of property for the erection of the first installation, the writer was directed by the President of the Borough of Richmond to examine a number of British refuse destructors in actual operation, so that the various reports might be verified and the differences in composition, quantity, and quality of refuse noted, in addition to obtaining data whereby the best type of modern destructor could be secured. Particular instructions were given to observe the weak points in mixed-refuse destruction.

During May and June, 1906, thirty-nine installations in Great Britain were inspected, and in August, 1906, the only destructor of the British type in the eastern part of North America, at Westmount, a suburb of Montreal, Canada, was visited in company with Louis L. Tribus, M. Am. Soc. C. E., Consulting Engineer to the President of the Borough of Richmond. Thus forty destructors were examined, thirty of which were in England, three in Wales, three in Ireland, three in Scotland, and one in Canada.

In covering a large field, wherein variations in type and design of destructors burning different kinds of refuse were encountered, a better general knowledge of the results attained in disposing of refuse was secured than if attention had been concentrated on a smaller number of plants.

Efforts were made to obtain complete data following a schedule covering the main factors in the process of mixed-refuse destruction, so that the various features of each installation might be tabulated

DEDUCTIONS.		
...ectionable features.	Commendable features.	Remarks.
... inside building and ...linker yard. Some ...oke in building....	Large plant, solidly built, well operated. Good power production. By-products utilized	Destructor portion fitted into general design made by consulting engineer.
... inside plant and in ...nker yard. Small ...ount of smoke ...m feeding doors ...en charging........	Well-designed, constructed and operated plant. Light and ventilation excellent. Working under easy conditions..	Authorities required that no refuse should be handled.
... in and around ...lding. Top-feeding ...perfect. Cramped ...rking space and ...k of light and air ...clinkering floor....	Well-constructed buildings. Furnaces 11 years in operation. Older type of plant, but still doing fair work in disposing of refuse........	Repairs under way caused plant to be inspected under worst conditions.
... storage of refuse ...floor in rear of fur...ces not desirable...	Clean plant, well designed, constructed and operated. Working under easy and comfortable conditions. Saves a fuel bill of £370 ($1 818) per annum.....	No inclined roadway provided because of considerations of cost.
... inside building and ...ut clinker yard....	Saves a fuel bill of about £900 ($4 410) per annum. Plant well designed, constructed and operated	
... and smoke inside ...lding. Stoking and ...kering space badly ...anged......	Plant well operated, substantially constructed. Working under easy conditions..............	
...lete type of de...uctor..............	Furnace twenty years in operation..............	
...icted site. Stok... and clinkering ...formed under dif...ulties.............	High temperature. Furnaces well built	Destructor was required by the authorities to fit a very restricted site.

and compared with other plants visited. The facts secured at the different destructors were checked by comparison with published data where such were available.

Table 10 represents in condensed form the results of the writer's observations on the forty destructors examined. In summarizing and discussing British practice in refuse collection and destruction, the general order of the headings in Table 10 will be followed.

The Collection of Refuse.—British household refuse, consisting of ashes, garbage, and rubbish, is thrown into one can, bin, or ash-pit by the householder. The materials are then dumped or shoveled into a wagon or cart and removed to the place of final disposition. Organic waste (garbage) is not separated from ashes and rubbish, as is usually the practice in the large cities of the United States, where the reduction system has been generally adopted.

Municipal ownership and operation of the refuse-collection service in Great Britain is general, and the contract system is almost unknown. Single-horse covered wagons or vans, holding about 3 cu. yd. of material, are common in the larger cities, and the type of horse used is rather superior to any noticed in the vicinity of New York, on similar work.

Frequency of Collection.—Refuse is collected weekly in Great Britain, as a rule, though in some municipalities the material is removed daily, while in other cities, where the old-style ash-pit system is in use, a monthly clean-out is common. To an American acquainted with the daily collection of garbage in the large cities of the United States, this delay in removal may seem to be unsanitary, especially in summer, when organic wastes decompose rapidly, but differences in conditions explain the matter:

First.—Ashes, garbage and rubbish are thrown together into one receptacle, and the ashes absorb the excess of water and tend to deodorize or retard the decomposition of the garbage.

Second.—The average Briton is not as wasteful as the average inhabitant of Richmond Borough, as the figures in Table 11 indicate.

Thus the period during which the ordinary refuse receptacle overflows will be longer in Great Britain than in the West New Brighton District, for which accurate figures have been compiled.

Third.—Differences in climate and in the habits of the people may explain further the long-time period of refuse collection practiced in Great Britain.

TABLE 11.

Locality.	Tons (of 2 000 lb.) per 1 000 inhabitants per day.	Authority.
Average, England	0.88	George Watson.
South of England	0.56 to 0.84	H. N. Leask.
Middle England	1.12	H. N. Leask.
Northeastern England	2.24	H. N. Leask.
Tottenham, England	0.68	J. E. Butler-Hogan, M. D.
Bradford, England	1.176	Ernest Call.
Glasgow, Scotland	0.86	D. McColl.
Dublin, Ireland	0.886	F. J. Allen.
Richmond Borough, N. Y.		
Average	1.59	Author.
Maximum (winter-spring)	1.94	Author.
Minimum (summer)	1.18	Author.

The Cost of Collection.—English municipalities generally have excellent accounting systems, but poor cost-keeping methods, though in some cases both accounting and cost-keeping are in advance of most American cities.

Figures on the cost of collection of refuse (which includes removal to the place of final disposition) were available at four places, as follows:

Tottenham, England	$0.56	per ton of 2 000 lb.
Swansea, Wales (about)	0.67	" " " " "
Glasgow, Scotland (one year)	0.63	" " " " "
Bradford, England (one year)	0.68	" " " " "
Average	$0.635	" " " " "

In a later paragraph, the average labor cost for destroying mixed refuse in some British destructors is shown to be $0.215, hence the cost of collecting the material is about three times the cost of destroying it, when operating expenses alone are considered. Thus, in any system of final disposition of refuse, the cost of collection becomes a most important factor in the economy of the method.

Composition of Refuse.—The word refuse, used in this portion of the paper, refers to household refuse alone, as street sweepings were not burned at any of the plants visited. In some special cases, however, night-soil and dead animals were cremated at the destructors.

Household refuse will vary in composition according to:

(a).—The geographical position of the city and its relation to the fuel and food supply;

PLATE CI.
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TABLE ND DEDUCTION

s.

Appurte	l notes.	Ap tem m tin in F	Commendable features.	Remarks.
ells are separat three working stoking and clin slides down an from rear and c at lowest level..	ull. Tempera- Smoke from rs............		....	
imney of bric Brick buildings tion in adjo Supplementary plant. Not enou able to run fu capacity........	, constructed rated plant. ght and air in Dust from nd flue clean-		Excellent plant. High temperatures. Steady steaming. Clinker utilized................	
ulnois, Wood & charging trucks arranged for co elevated to top power, then dro ng trucks. T ystem in use...	ding dusty; ping from top- ors; odors		Plant well operated; very complete records of costs available.......	It should be noted that the repairs under way at time of visit might cause some of the objectionable features.
fuse stored on or forced draf hood under w ooled by a spra ny obnoxious rom the cooli assed back thr	ing ports cov- refuse; dust n tipping top of cells. tem for refuse design.......		Plant well managed; developing 68 electrical units per ton of refuse burned..................	
w furnace ver onstructed. T tion is doing building is large ght and air; gl n interior walls	g under easy		Substantial plant, doing excellent work; said to save £1 000 ($4 900) per annum in coal bills......	
parate room fo torage of re nental coal-fired se when dest orking	an and well ctor in good	Fu	Excellent plant; well managed; central location; refuse tipped and stored in separate building. Saves £400 ($1 960) net in fuel bills.........	
ry substantia building open i ge hopper. ower station n	....	No	Well-constructed plant, of modern design.......	
ad animals cre ustion chambe designed for sewage sludge, b f sludge was brick chimney corrugated iron	managed and ted; power ious purposes oration yard..		Furnaces duplicated to avoid complete shut-down for cleaning; clinker well utilized. Saves in fuel £650 ($3 185) per annum.....	

(b).—The particular district of the city considered, as business, residential, tenement, or manufacturing;
(c).—The character and habits of the people;
(d).—The season of the year.

Very little attention has been given by municipal engineers to determining the composition and calorific value of British refuse, and so only scattered data are available for comparison with the refuse of other countries. British destructor makers, however, base their guaranties of power production upon an examination of the refuse in each locality. This involves a previous experience with results obtained under like conditions at other places. Thus a sight valuation or estimate of the composition of refuse in different cities should be of service in determining the feasibility of burning refuse without the use of additional fuel, and for comparing results in power production.

At each plant an estimate, by weight, was made of four general components of refuse, *viz.:* (1) ashes, including other small inorganic materials; (2) garbage, or organic matter; (3) rubbish, or paper, straw and such light combustible materials; and (4) glass, metal, etc. Some previous experience helped the writer in this respect, though it should be understood that the figures for the different cities shown in Table 10 are based upon the quantity of refuse on hand when each plant was visited, and are merely rough estimates.

At first sight, the difference in general appearance of British refuse and that found in the vicinity of New York was apparent. The color of British refuse is dark brown to black, due to the soft coal ashes, while ashes from hard coal, such as used in New York, are light gray in color. Again, British refuse varies in appearance and composition with the distance from the coal fields, the character of the district, and the habits of the people. In London and the south of England, the refuse is rather lighter in color than that found in Middle England in or near the colliery districts, where it is darker, and more unconsumed lump coal is visible.

In comparing American household refuse with the estimates given in Table 10, localities having the same general characteristics and for the same period of the year should be chosen. On this basis, as a general conclusion, the writer is of the opinion that British refuse

contains more ashes, less garbage, less rubbish and more moisture than household refuse in the vicinity of New York, though the higher percentage of moisture during May and June, 1906, might have been due to a prolonged rainy period. From such information as was obtainable regarding the composition of British refuse, it would appear that no such seasonal variations occur as may be found in comparing American summer with American winter refuse, while, during the fruit season, British refuse contains no wastes comparable to melon rinds and corn cobs.

A superficial observation of British refuse is apt to prove deceptive in the amount of garbage present in the mixed mass, as the dark ash tends to cover and conceal garbage which would otherwise be quite apparent in the lighter colored anthracite ash.

Apparent Value as a Fuel.—That British refuse has a fuel value is proved beyond a doubt by the two hundred or more destructors in which refuse is burned throughout the year without additional fuel. There would seem to be no large seasonal variation in the calorific power of the material, though in one instance a difference in steam production of 15% less in summer than in winter has been noted.

The average evaporation for eighteen tests quoted in Table 10 amounts to 1.62 lb. of water per pound of refuse. Assuming an efficiency of 50% (boiler and grate) per pound of refuse, the calorific value of the average material burned during the tests would amount to 3 130 B. t. u., which practically agrees with the estimated calorific power of average British refuse given by various authorities on the subject.

Location of Plants.—The location of a plant for the final disposition of refuse has a most important bearing on the cost of the collection (including removal) of the material. Economy in collection requires that the plant shall be centrally located with regard to the district served, and that loaded collection wagons or carts shall proceed with the road gradient.

Of the forty destructors, four were critically located, so that the least nuisance would probably result in the abandonment of the plants; seventeen were centrally located in advantageous positions with regard to the district served, but the surrounding houses were not in close proximity to the destructors; nineteen were placed on the outskirts of towns and not likely to cause complaint, even if the plants were not well operated.

Approximate temperature of main flue at time of visit, in degrees, Fahrenheit.	Utilization of By-Products. Clinker.	Flue dust.	Tins, etc.	Reported evaporation per pound of refuse, from and at 212° fahr.	
...ow; about 1 400	Sold at 2s. (50c.) per ton...............	....	Sold at 17s. 6d. ($4.37) per ton.	....	S
1 800	Used for making footpaths. Proposed use in bacteria beds........	Proposed use as a base for carbolic powder..	Sold at 6d. (12c.) per ton.	1.48 lb. in 10½-hour test	N
1 800+	Crushed, screened and sold or used for road bottoming................	Used as a base for disinfectant...........	Sold at 5s. ($1.25) per ton.	2.66 lb. in 15-hour test	N
1 800+	Used for filling adjacent ravine.....	Used for filling...	....	2.16 lb. in 7¼-hour test...............	N
2 000	Made into mortar or clinker concrete and used for building sewers, retaining walls, etc., or dumped on adjoining fill........	....	To be baled and sold.	1.20 lb. in 23-hour test...............	N
...ot working when visited	Used for footpaths or for filling......	Used for filling.	Carted off.	....	N
...ot working	Sold at 6d. (12c.) per load..............	....	Sold......	....	N
....	To be utilized........	....	To be baled in a press and sold.	....	N

Complaints of nuisance due to the location of British refuse destructors in settled localities are said to be rare, and, as far as could be determined, very few of the plants visited deserved condemnation in this respect. The photographs which accompany this report indicate beyond a doubt that mixed-refuse destructors can safely be placed in central localities.

Certainly the town councilmen of Bermondsey Borough, London, would not allow a nuisance directly in the rear of the Town Hall (Figs. 1 and 2, Plate XCVII), nor would the people living about the Sheerness destructor (Figs. 3 and 4, Plate XCVII) permit an ill-smelling plant to continue in existence. At Wrexham, in Wales, (Figs. 1 and 2, Plate XCVIII), the destructor is critically situated, and at Rathmines, just outside Dublin, Ireland, the destructor is in the rear of the Town Hall (Fig. 3, Plate XCVIII), with houses near-by. In many other cases destructors are located so that any nuisance would certainly result in complaints by people living in the vicinity, and probably end by closing the plant.

It is not advisable, however, to place a refuse destructor in the midst of higher inhabited buildings, as the dust, with possibly an occasional escape of smoke, may cause some annoyance, though even this trouble can be obviated by proper attention to details in the design of the destructor building.

Types of Destructors.—In the forty plants inspected, ten different kinds of furnaces were represented, as follows:

Name of Furnace.	Number Inspected.
Meldrum	13
Horsfall	10
Heenan	6
Beaman and Deas (Meldrum)	2
Warner	3
Fryer's Improved (Manlove-Alliott and Company)	2
Fryer's	1
Sterling	1
Baker's	1
Glasgow (local design)	1

All these destructors contain large brickwork chambers having fixed grates with boilers placed outside the refuse-burning portion. In

the destruction of refuse by fire, well-determined principles of combustion apply. In order that nuisance may be prevented, it is necessary that all combustible portions of the refuse shall be completely consumed, with the result of producing the highest state of oxidation. According to Professor Thurston, the requirements for success in burning wet fuel are:

"The surrounding of the mass so completely with heated surfaces and with burning fuel that it may be rapidly dried, and then so arranging the apparatus that thorough combustion may be secured, and that the rapidity of combustion may be precisely equal to and never exceed the rapidity of desiccation. Where this rapidity of combustion is exceeded, the dry portion is consumed completely, leaving an uncovered mass of fuel which refuses to take fire."*

In practice, the destruction of refuse may be attained successfully by burning it by forced draft in a so-called Dutch oven or chamber where the brickwork is maintained at a high heat, and the escaping gases are subjected to a high temperature with an excess of air for a sufficient length of time to oxidize the combustible constituents of the material. British destructors are designed in accordance with the above principles.

The forms or types of destructors vary, however, and for convenience may be divided into two general groups.

Group 1.—The first may be termed the mutual assistance type, where one unit contains several grates with divided ash-pits, the products of combustion intermingling in the upper portion of the furnace, thus combining several furnaces or cells in one. Representatives of this type are the Meldrum and Heenan.

Group 2.—The second comprises furnaces in which each burning grate or cell forms a separate unit. The products of combustion either commingle in a general flue or combustion chamber, or pass directly from cell to boiler. Representatives of the cell type in which the products of combustion intermingle in a common chamber before passing to the boiler are the Horsfall, Sterling, and Beaman and Deas (Meldrum). Representatives of the type in which the products of combustion pass directly from the cell into contact with the boiler are the original Fryer, Fryer's Improved (Manlove-Alliott and Company), Warner, and Baker.

The Meldrum, Heenan, and Horsfall types pre-heat the air used

* "Steam Boiler Economy," Kent.

...DUCTIONS.

...ERVATIONS.

...eneral notes.	Approximate temperature of main flue at time of visit, in degrees, Fahrenheit.	...Commendable features.	Remarks.
...ell managed and ...perated. Working when visited.......	1 800+	...ll-constructed and well-managed plant. Good power production. Back hand-feeding and front-clinkering advantageous..........	
...sive plant for loca-... Well operated. ... about building.....	Low; 1 800	...expensive plant doing a fair amount of work..	
...ell-managed plant. ... one district of ...w. Low cost of ...ion................	2 000	...gh temperature. Low cost of operation. Excellent management and operation..........	The whole scheme of refuse disposal in Glasgow shows careful planning over a period of years, resulting in economy and efficiency. Night collection of refuse is the rule.
...naged, clean plant, ...lly operated. Low ...f destruction.......	Rather low when visited. 1 400	...ell-built, carefully operated plant. Low cost of operation.......	
...arefully operated. ...ay's refuse rapidly ...ed of...............	Old furnace not working when visited.	...onomical means of disposal, but not very sanitary. Plant carefully operated..........	
...experimental stage. ...running for a short ... Chimney area said inadequate..........	Very high: 2 000+	...gh rate of burning. No handling of refuse. Cool storage of refuse. Probable economy in labor cost of destroying the refuse..............	The old Fryer destructor consists of 14 cells; top feed, with Horsfall steam jet blowers. The two new Horsfall cells will destroy as much refuse per day as seven of the old Fryer cells.
...ell designed for ease ...ration and comfort ... men. Dust nuisance ...ntrolled by system ...tilation.............	1 800+	...cellent plant in design and construction. Independent destructor units. Controlled ventilation. No supplemental coal-fired boiler plant....................	
...y clean and well kept.	1 800	...ttractive building. Well-designed, constructed and operated plant. Said to save £1 000 ($4 900) per annum in coal bills........	Top feeding required by authorities.

for combustion to a temperature from 200 to 400° fahr. before it comes in contact with the burning fuel on the grate. Other makes of furnaces mentioned in Group 2 use air at ordinary atmospheric temperature. The utilization of heated air undoubtedly tends to more perfect combustion and higher temperatures both in cell and combustion chamber. Other differences in design, in the furnaces in Groups 1 and 2, may be noted, as for instance, the drying hearth which some furnace makers consider essential in the destruction of refuse, the use of steam-jet blowers or fans for forced draft, the different provisions for arresting dust, the kind of boilers used, the various methods of feeding, clinkering, stoking, etc. All the above-named destructors, except the original Fryer, use forced draft, which is considered necessary for the attainment of a high temperature.

The aim in the design of refuse destructors should be to maintain a steady temperature. If it be considered that 1 250° fahr. is the minimum at which septic poisons in the products of combustion are destroyed, the higher limit of temperature is fixed by the materials used in the construction of the furnace. Temperatures greater than 2 000° fahr. are apt to result in high cost of repairs. Thus temperatures between 1 250 and 2 000° fahr. are desirable, both from sanitary and economical points of view. As the burning of refuse in a destructor is an intermittent process, requiring alternate charging and clinkering, the fluctuations in temperature should be minimized as much as possible. When destructors are of such design that the gases pass directly from cell to boiler without an intermediate combustion chamber, there is danger of unoxidized gases being cooled, by contact with the boiler, below the temperature required to prevent nuisance.

In general, modern British types of destructor vary in important details, and, of the different plants examined by the writer, those in which a combustion chamber or flue was placed between the cell (or unit) and the boiler, and where heated air was used for combustion, appeared to be doing the most satisfactory work.

Power from Refuse.—Of the forty plants inspected, all but two produced steam for power purposes, as follows:

Power Used For:	Number of Plants.
Electric lighting and power stations	16
Sewage pumping	7
Works purposes	14
Water pumping	1

In considering the utilization of power from refuse, it should be borne in mind that power is a secondary consideration, and that the primary object is to destroy refuse in a sanitary and economical manner.

At electric lighting and power stations, the demand for lighting purposes generally occurs for a short period in the evening, when an output very much higher than the ordinary working load is required. With refuse which is of low calorific value, and requires burning at a high rate to produce power, this means that the fires must be rushed, and consequently there is likelihood of incomplete combustion. Supplementary coal-fired boilers are usually found in connection with destructor-electric-lighting stations, or else the destructor is of much greater capacity than would be required to deal with the refuse only. The combination of refuse destructor and electric lighting plant may be economical, yet, if other means are available, whereby the power resulting from the destruction of refuse can be utilized regularly as produced and the furnace operated continuously at an easy working rate, this method should prove more desirable than electric lighting utilization. At the sewage pumping stations visited, the quantity to be pumped was usually insufficient to keep the destructor continuously in operation. Pumping water by the power produced from refuse would seem to be the most satisfactory method of utilization, but the conditions where such a system can be used are exceptional.

If no other outlet for the energy produced in burning the waste material is available, the power is used for what has been termed "Works Purposes," that is, crushing clinker, screening it into different sizes, mixing it with mortar, cement, or lime, to form bricks, slabs, etc., also for lighting the destructor depots or adjoining corporation yards, and the steam heating of neighboring public baths or libraries.

It is undoubtedly advisable to provide means for utilizing heat resulting from the destruction of city wastes, for the purpose of decreasing the cost of final disposition. At the same time, it should be kept in mind that a sanitary disposal of refuse is the primary consideration. There were indications at some refuse destructor plants in Great Britain of a tendency to slight the main factor of sanitary disposal.

Capital Cost of Destructor Installations.—The cost of construction of destructor installations varies greatly according to local conditions,

and figures for British plants would hardly apply in the United States. It appears from the data obtained, however (the details of which are given in Table 10), that the average cost of eighteen destructors would amount to about $4 470 per cell or grate, including the furnace with boiler and appurtenances, but excluding chimney, building and runway.

Cost of Operation.—The cost of operation, for different plants quoted in Table 10, was obtained from the engineer or superintendent in charge of the destructor or from the furnace makers. Some of the figures given are from official reports covering a year's work, while others are for short periods only. From the data, it appears that for twenty-four installations the average cost of labor per long ton (2 240 lb.) of refuse destroyed would amount to 24.3 cents, or 21.5 cents per short ton (2 000 lb.). As the American rate of laborers' wages is about double the British rate, this would make 43 cents per short ton of refuse destroyed on an American basis.

For supervision, only four installations had figures available, the average being 4.83 cents per long ton. Two plants reported the cost for repairs at 3.22 cents per long ton.

Only one complete report was obtained in which all charges for the destruction of refuse, including labor, supervision, interest on capital, sinking fund, repairs and supplies, were included. The total cost of operation, including all the above charges at Stoke-upon-Trent, amounted to $1.17 per long ton or $1.04 per short ton. By changing the labor rate so that it would compare with American conditions, and by assuming the same charges for interest, sinking fund and repairs, it would appear that the total cost of refuse destruction for a plant similar to that at Stoke-upon-Trent would amount to $1.50 per short ton in New York.

Of the various figures tabulated for the labor cost per long ton of refuse destroyed, it will be found that eleven destructors—in which refuse is fed into the furnace by hand—returned an average cost of 21.6 cents as against 27.3 cents for eleven top-fed destructors. Some figures used in making up the foregoing results for hand-fed plants covered only a short period of time. It is of interest, however, to note that hand-feeding does not seem to be more costly than top-feeding.

Refuse Burned per Man per Hour.—Definite information regarding the quantity of refuse handled per man per hour (assuming the

quality of labor to be comparable) affords a better general means for arriving at the labor cost of operating a destructor. From the figures for twenty-seven plants, on an average, each man employed would handle 0.78 long tons or 0.88 short tons per hour, varying from 0.5 to 2 long tons per hour with the type of plant and method of operation. At an easy rate of working, there should be no difficulty in destroying 0.75 short tons per man per hour; hence, with wages at 25 cents per hour (or $2 per day), the cost of labor would amount to 33⅓ cents per ton, while at 31¼ cents per hour (or $2.50 per day), the cost would be about 42 cents per ton.

Special Notes on Destructors.—In glancing over the various photographs which accompany this paper, it will be apparent that the English destructor is most substantially constructed, and that the buildings are intended for long service. From an examination of the various older furnaces, it would appear that the destructor portion, with ordinary care in operation, should last at least fifteen years.

As the appearance of a refuse installation has an important bearing on public opinion regarding the plant, it is of particular importance that the building should be made attractive, architecturally. The interior should have ample light, air, and provision for the comfort of the men employed, including baths and toilet facilities. These features have received consideration in Great Britain, as some of the photographs indicate.

Another factor requiring consideration is the extent of ground surrounding the destructor building. Ample land should be provided, if possible, so that dust may not cause complaint from neighboring householders.

Operation of Plant—Observations.—In the time spent at the various installations, many features of interest undoubtedly escaped attention, and perhaps some of the comments in Table 10 would hardly be warranted if some days instead of hours had been given to each. The recorded observations, however, indicate the conditions at the time the plant was visited. Generally speaking, from the appearance of the destructors, no special preparations were made because of the writer's visit, and in many cases no warning was given to those in charge.

Feeding—Charging.—Of the forty destructors, sixteen were of the top-fed variety, in which refuse was charged through ports on top of

Fig. 1. Watford Destructor, Sewage Pumping Station, and Electric Lighting Plant.

Fig. 2.—Walthamstow Destructor at Sewage Farm, with Precipitation Tanks in Foreground.

Fig. 3.—Combined Electric Lighting and Destructor Station at Stoke-upon-Trent.

Fig. 4.—Combined Destructor and Sewage Pumping Station at Worthing.

the furnaces, and these sixteen represented nine different types. Three installations were top-fed by cart direct, and represented two types of furnace. By "cart fed direct" is meant that cart storage of refuse was necessary, and when the furnace was ready for charging each cartload was dumped directly into the cell. One furnace was top-fed by a so-called "tub-feeding" method. In this case, each cart was tipped at the ground level into a box or tub with hinged bottom doors. The tub was then elevated by a traveling crane, and the charge of refuse was dropped into the cell through water-sealed mechanically-operated doors on the top of the furnace. One destructor was top-fed by a patent charging truck. Here, also, refuse was elevated by power, dropped into a truck on wheels, and charged into the furnace as required. Eleven destructors were hand-fed at the front by shovel, and represented two types. Eight destructors were hand-fed by shovel at the back, and represented three types.

In commenting upon the different methods of charging destructors, it appears that the top-feeding method (except where water-sealed doors are used) allows smoke to escape. Even with water-sealed doors, smoke escapes when charging. Of the hand-firing methods, the front-fed type appears to be advantageous, with regard to concentration of labor and freedom from escaping smoke, but the storage bin cuts off light and air from the firemen, while some refuse may be mixed with clinker if the men are careless. With back hand-feeding by shovel, ample light and air can be given on the clinkering side of the furnace where it is most needed. As compared with front-feeding, back hand-feeding does not permit of the same concentration of labor, but allows greater comfort to the men employed, which more than compensates for this slight disadvantage.

In general, shovel-feeding obviates escaping smoke from top-feeding doors, allows a better selection of refuse, and does away with stoking to a great extent, as refuse can be charged directly on the grate, thus saving one operation in destroying the material. When the refuse has not reached an advanced stage of decomposition, and does not contain an excess of water, or such objectionable material as night-soil, hand-firing is undoubtedly to be preferred, especially for power plants.

Stoking.—By stoking is meant the dragging, pushing or spreading of refuse after it has been charged into the furnace. All top-fed

destructors and all destructors provided with drying hearths require considerable stoking. Hand-fed types, without drying hearths, where refuse is thrown directly on the grate, do not need much stoking.

At first sight, it would seem that refuse charged direct from cart to cell without intermediate handling should prove most sanitary and economical, yet the disadvantages of this method are many. For any particular case, a study of local conditions will determine the best system to be used.

Clinkering.—Clinkering is perhaps the most trying work in connection with the operation of a destructor. A mass of hot slag must be broken up by long bars, tipped into a wheel-barrow or other conveyance, and removed while in a highly heated condition. The work is performed by hand labor opposite the open doors of a highly heated furnace. There are various methods of conveying clinker, as by wheel-barrows, by cars on rails, or by skips running on an over-head rail. When cars or mono-railways are used, the storage room is limited, and the place where the material is deposited must be cleared at intervals; for this reason, the system has been abandoned in favor of wheel-barrows at many plants.

Various mechanical devices, such as tipping grates, etc., have been tried in order to lessen the work of clinkering, but, up to the present time, all have failed. At Westmount, in Canada, the destructor site was well adapted for a clinker pit, whereby clinker, instead of being removed in barrows or cars while hot, is dropped through a trap-door in front of the furnace to a lower level, where it is allowed to cool. This is a decided advance over the usual practice. A further improvement might be made at Westmount by enclosing the pit and utilizing the heat contained in the hot clinker for raising the temperature of air for combustion.

Character of Clinker.—As a general rule, the clinker in sight at the various installations was found to be hard and well-burned, except where plants were carelessly operated, or where fires were rushed at some electric lighting stations. In order that clinker shall be dense and that practically all the carbon shall be oxidized, it is necessary that the clinker be exposed to a high temperature for a sufficient time to consume thoroughly all the combustible material.

General Notes on Operation.—As with other works, the method of operating a destructor may mean its success or failure. A well-de-

FIG. 1.—SWANSEA DESTRUCTOR AND ELECTRIC POWER HOUSE.

FIG. 2.—COMBINED DESTRUCTOR AND ELECTRIC LIGHTING STATION AT WESTMOUNT, CANADA.

FIG. 3.—HAMMERTON STREET DESTRUCTOR WORKS, BRADFORD.

FIG. 4.—BATLEY COMBINED DESTRUCTOR AND ELECTRIC POWER STATION.

signed plant poorly operated may give rise to nuisance, whereas a poorly-designed plant efficiently operated may cause no trouble whatever. At most installations it was manifest whether or not the authorities were interested in the sanitary disposal of refuse. In poorly-operated plants, dirt, dust, and smoke were in evidence, while in efficiently-managed installations, cleanliness, order, and system were the rule. Of all destructors visited, there were few in which dust, either from the refuse on storage, or from the process of clinkering, was not a cause of inconvenience, though the trouble was usually confined to the destructor building.

The necessity for a systematic routine in the operation of refuse destructors was quite apparent, and in some of the plants the firemen worked practically by the clock. Each step in the process of feeding, stoking, or clinkering was performed regularly at stated intervals, thus tending to efficiency in management. Few self-recording devices or checks on the operations, such as steam gauges, chimney gas analysis apparatus, draft gauges, pyrometers or thermometers, were noticed at the various plants.

Temperatures.—At each destructor in operation a sight estimate of the temperature of the main flue or combustion chamber was noted, as this factor has a decided bearing upon the freedom from nuisance and the efficiency of any installation. It is of great importance, both from sanitary and economical points of view, that temperatures be regulated between a lower limit of 1 250° fahr. and a higher limit of perhaps 2 000° fahr. When the temperature is high, the gas escaping from the chimney is almost colorless, but when charging or clinkering operations are in progress, murky to dense white smoke may be apparent for a short time. As a rule, gases escaping from the destructor chimneys showed no color when compared with the black clouds emitted from the chimneys of neighboring manufacturing establishments in Great Britain.

Utilization of By-Products.—By-products resulting from the destruction of refuse, excluding the steam generated by the heated gases, consist of clinker from the grates, fine ash from the ash-pit, and flue dust from the combustion chamber or flues, besides tins, bottles and earthenware which may or may not be passed through the furnace.

Clinker.—Clinker, when burned to a hard vitreous mass, is utilized as an aggregate, mixed with cement, and made into slabs, bricks or

mortar, usually by hydraulic presses or mortar mills. If not thus utilized, it may be used for road bottoming, sidewalks, or for filling low land. The question of clinker utilization is usually decided by local conditions. Where clinker can be sold or used advantageously in making slabs, bricks, etc., machinery is usually installed, and the process results in reducing the total cost of destruction. At Worthing, on the south coast of England, clinker has been mixed with tar and used as a road pavement. The revenue derived from the sale of clinker will vary with the demand in any locality. Six municipalities report clinker sold at an average price of 42 cents per long ton.

Flue Dust.—In burning mixed refuse, some fine incombustible material finds its way into the destructor flue or dust traps, and must be removed periodically. This may have an important bearing upon the actual capacity of a destructor, as it may be necessary to shut down the plant for several days while the cleaning process is under way. The time elapsing between cleaning periods varies with the character of the material destroyed and the type of destructor. It would appear to be necessary to clean out all flues thoroughly once every 4 to 6 weeks in Great Britain, except where a special form of dust-catcher is used.

Flue dust has been used as a base for disinfecting powder.

Tins.—Refuse contains a large quantity of tinware, varying in size from food cans to boilers and wash-tubs. These articles are not usually put through the destructor, but are thrown to one side and sold in bulk or compressed by a machine into suitable bundles. At some plants, solder is melted from tins in a special furnace, and the resulting products, solder and iron, are sold to junk dealers. The revenue from the sale of tins will depend on local considerations.

Power from Refuse.—Figures for eighteen destructor tests, giving the quantity of water evaporated per pound of refuse ("from and at 212° fahr.") for periods varying from 6½ hours to one year were secured. The highest rate of evaporation was 2.66 lb. of water per pound of refuse, in a 15-hour run at a destructor in a colliery district. The lowest gave 0.88 lb. of water per pound of material, in a test of 11½ days, with refuse containing a large proportion of night-soil. The average evaporation in eighteen modern destructor tests amounted to 1.62 lb. of water per pound of refuse. In all the foregoing figures the water evaporated is a gross amount, and in order to obtain the

FIG. 1.—CLINKER CAR, BROMLEY.

FIG. 3.—CLINKER YARD AT KETTERING, WITH HOUSES ADJOINING DESTRUCTOR BUILDING.

FIG. 2.—CLINKERING FLOOR AND DESTRUCTOR UNITS AT KINGS NORTON.

FIG. 4.—CLINKER RAILWAY AND YARD AT SUNBRIDGE ROAD DESTRUCTOR, BRADFORD.

net useful steam produced for power purposes it is necessary to deduct for forced draft apparatus. It appears, from the figures quoted, that, in a district where coal is abundant and cheap, it is possible to evaporate about 2.5 lb. of water per pound of refuse, while in other districts, distant from coal fields, destructors are capable of producing an evaporation of about 1.5 lb. per pound of refuse.

A test of a refuse destructor for a few hours hardly gives a safe figure upon which to base conclusions on power production, as the material may vary in character and calorific value with the season of the year. It is of interest to note in Table 10 that the destructor at Westmount, Canada, evaporated 1.36 lb. of water per pound of refuse in a test run of 8½ hours on May 2d, 1906. The refuse on storage at Westmount in August, 1906, was much drier, and contained a larger proportion of rubbish and ashes than the material for a similar period in Richmond Borough.

Deductions.

From data and observations made upon the various destructors, the following deductions were made:

Nuisances or Possible Cause of Complaint.—This heading means that, of the plants examined, some might, if situated in a critical position, give rise to complaints by inhabitants of the neighborhood. There is no intention of condemning any installations on the score of nuisance, as no doubt any destructor which had proved objectionable would have been closed by legal procedure.

It is possible that, of the forty installations, nine might cause complaint through the escape of unconsumed gases, poor operation of plant, or bad design.

Objectionable Features.—At the forty destructors an objectionable feature common to all was that due to the escape of dust, either from the refuse on storage, from the clinkering operations, or during the removal of flue dust. This dust, unless it escapes through the chimney, becomes a nuisance which affects only the workers about the plant, and anything that may be done to minimize it will mean a decided advance over present practice.

At sixteen plants, smoke or unconsumed gases were escaping through feeding ports, stoking or clinkering doors.

The system of storing refuse at six installations was objectionable because the firemen were obliged to work in the material when charg-

ing. At six plants the working space was cramped, and there was a lack of light and air, causing discomfort to the men. At two destructors the method of feeding refuse was objectionable because of complicated mechanical devices. At only two out of the forty plants were unconsumed particles of organic matter noted in the clinker. This was undoubtedly due to lack of efficient operation, or negligence on the part of the firemen.

Commendable Features.—Summing up the commendable features of the different installations, it may be said that practically every plant had some feature which would call for approval. In general, all the destructors were well constructed and designed for hard service. The buildings were usually of brick, substantial, and in some cases of attractive appearance. With but one exception, all the destructors were disposing of refuse without the use of additional fuel, and in the case noted, coal was used only during wet periods in summer.

Temperatures were generally sufficiently high to prevent the escape of unconsumed gases. Steam raising was practiced at all but two of the plants, and the amount of power produced had an important bearing on the economy of the process. Clinker, resulting from the burning of refuse, was sold or utilized for different purposes, tending to further economy in operation, while flue dust and tins were utilized.

Mixed-refuse destruction, whereby waste material discarded by householders is disposed of without nuisance and the resulting by-products are turned to useful purposes, would seem to be an ideal system. Certainly, in so far as sanitary disposal is concerned, mixed-refuse destruction, efficiently conducted, should cause no trouble if the material be of fair quality. While it is not possible at the present time to do more than estimate the cost of such a method in the vicinity of New York, it would appear that mixed-refuse destruction should not cost much more than garbage cremation in Richmond Borough, while the sanitary advantages accruing would more than compensate for any slight excess in cost.

Recommendations for a Mixed-Refuse Destructor Installation in the Borough of Richmond, West New Brighton District.

In view of the local experiments and experience gained abroad, the details of which are partially recorded herein, the writer recommended for the first installation at West New Brighton, in the Borough of Richmond:

FIG. 1.—WOOLWICH DESTRUCTOR YARD. PILES OF CLINKER BRICK.

FIG. 3.—YARD AT WALTHAMSTOW, WITH PILES OF SLABS MADE FROM CLINKER.

FIG. 2.—MORTAR MILLS AT SUNBRIDGE ROAD PLANT, BRADFORD.

FIG. 4.—CHIMNEY AT WESTMOUNT, WITH DESTRUCTOR IN OPERATION.

1.—A hand-fed destructor charged at the back of the furnace and clinkering on the opposite side or front of the furnace.

2.—That refuse be stored in a bin or hopper with a door or curtain to control and prevent the escape of dust into the destructor room while the hopper is being filled.

3.—That refuse be dumped into the bin or hopper behind closed doors; and that the refuse storage room be separated from the destructor portion of the building.

4.—That heated air be required for the combustion of refuse.

5.—That a water-tube boiler be specified.

6.—That steam-jet blowers, or fan-draft, or both, be provided so that the advantage of either may be determined.

7.—That the air for forced draft be drawn from the upper portion of the tipping-room and feeding or clinkering-room, so that positive ventilation may be secured.

8.—That the clinkering process be arranged so that hot clinker is dropped into a pit and the heat from the clinker is utilized in raising the temperature of the air for combustion.

9.—That ample working space, light, and air be provided in the building, and the plant be located so as to cause no trouble from escaping dust.

10.—That a suitable mess-room, bath and toilet-room be provided, for the comfort of the men employed.

11.—That the exterior of the plant be made attractive in appearance.

Contracts have been entered into with Messrs. Heenan and Froude, Ltd., for the erection of a 60-ton destructor, and with McHarg-Barton Company for the erection of the building, chimney, etc., at West New Brighton. The plant will probably be in working order before the close of 1907, and later, the writer hopes to present and compare the actual results with the preliminary studies herein outlined.

In conclusion, the writer desires to acknowledge his indebtedness to the Hon. George Cromwell, President of the Borough of Richmond, for his interest and encouragement; to Louis L. Tribus, M. Am. Soc. C. E., Consulting Engineer to the Borough President, for advice and support; to B. F. Welton, Assoc. M. Am. Soc. C. E., for his interest in the calorific tests, and for many valuable suggestions; to George Wood, Assoc. M. Am. Soc. C. E., for assistance on different portions

of the work; to the representatives of the different firms engaged in destructor building, particularly W. F. Goodrich, Assoc. M. Inst. M. E., Frank Rudder, Assoc. M. Inst. M. E., and George Watson, Assoc. M. Inst. C. E., also to the various municipal engineers, surveyors, superintendents, and managers of the British destructors examined, for their courtesy and assistance.

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ROTATING SCREEN OF POWER CANAL, SALT RIVER PROJECT.*

By F. Teichman, M. Am. Soc. C. E.

One feature of the Salt River Project, Arizona, United States Reclamation Service, is a power canal, 19 miles long, having a capacity of 250 cu. ft. per sec., and 240 ft. head. The power developed will eventually be used mainly in pumping for irrigation in the Phœnix Valley. At present the power is used for the construction of the reservoir dam across the Salt River Cañon, which includes the operation of a cement mill. The power is developed in turbine wheels with guide-buckets adjusted by the governor.

The water of the canal carries much sediment, and also a great deal of grass, sticks, etc., especially at times of heavy rains. These floating bodies are likely to lodge in the narrow end of the guide-buckets, and it may occur (as it has occurred) that, if these bodies are not kept out, the governor, in attempting to close the buckets at moments of small demand of power, will break the bucket which is blocked, and such breakage may be followed (and was followed) by breakage in the runner of the turbine.

To avoid such accidents it has become necessary to send the water of the power canal through a screen, naturally located at the penstock.

* This paper will not be presented at any meeting, but written communications on the subject are invited for publication with it in *Transactions*.

This screen is supposedly of a novel design, and, having proven successful in operation, it is thought that a short description may be of interest.

The screen has the form of a truncated cone, the water entering the cone at the base. The axis of the cone is at an inclination of 1 : 4. The cone is made to rotate slowly around its axis. To the entrance ring of the cone is fitted (with a small clearance of only ¼ in.) the stationary entrance ring. The screen of the cone is made of No. 18 galvanized wire, ½-in. mesh, and is supported by circular rods (⅝ and ¾ in. in diameter) which in their turn are supported by sixteen ¾ by 4-in. bars, riveted to the steel head of the drum at one end, and to the entrance ring at the other. At a point about two-sevenths of their length from the entrance ring the sixteen bars are connected and supported by the trunnion ring. Between the trunnion ring and the steel head these bars are connected by ⅞-in. stay-bolts. To the steel head is riveted a center casting, bored for a stationary shaft, 3 in. in diameter, held in a cast-iron shaft support. The structure of the screen, therefore, is supported by this 3-in. shaft and by two trunnions in the plane of the trunnion ring. To the steel head are bolted the segments of a cast-iron ratchet ring of 72 teeth, and a pawl, actuated by a crank-pin, worm-wheel, worm and motor, propels the screen, which makes a complete turn in about 1 hour.

The extension of the 3-in. shaft in the interior of the drum, and a concrete arch over the canal about 16 in. from the drum, support, in the interior of the drum, two 8-in. channels, slightly inclined, on which rests a galvanized-iron trough, 3½ ft. wide and 16½ ft. long, that terminates in a side trough. The motor which turns the screen also pumps water into a horizontal trough above the screen and centrally above the interior 3½-ft. trough. At intervals the upper trough opens automatically, and the water it contains is sprayed over the screen and into the interior trough, carrying with it any material which has lodged on the inner surface of the screen. Material which does not adhere to the screen is lifted by blades attached to the interior of the screen, and dropped into the interior trough. The wash-water carries the screenings through the side trough over the edge of the canal.

The area of the submerged screen is 232 sq. ft. with the canal discharging 250 cu. ft. per sec. The screen would safely stand a difference in level of the water, inside and outside, of 4 ft., which may possibly occur during the first heavy rains of the season.

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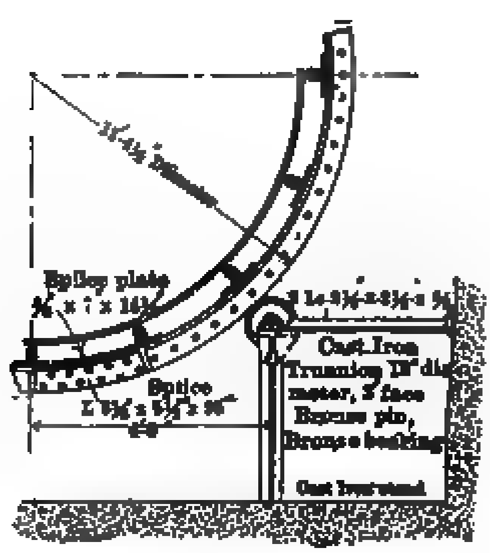

SECTION A-B

ROTATING SCREEN
AT
PENSTOCK OF POWER CANAL.
SALT RIVER PROJECT.

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REINFORCED CONCRETE TOWERS.

Discussion.*

By R. D. Coombs, Assoc. M. Am. Soc. C. E.

R. D. Coombs, Assoc. M. Am. Soc. C. E. (by letter).—The author states that "the greatest wind pressures in that part of the country have never exceeded an average of 30 lb. per sq. ft. on large areas." While the writer is very ready to admit the probability of this statement, he would inquire whether the author has any data on recorded velocities in the locality mentioned, as the wind pressure used would correspond approximately to a velocity of 102 miles per hour. **Mr. Coombs.**

It is not perhaps a part of the immediate subject of the paper, but it would be of interest to know the working stresses and factors of safety allowed in the span wires, insulators and other connections.

The author's assumption that all wires may break at once, at their ultimate tension, seems to the writer to be entirely unwarranted. Such an accident could only occur from:

First.—Some object striking the wires. This is very unlikely at the altitude given, and is practically impossible on account of the different planes in which the wires lie.

Second.—By the wires breaking under ice and wind loads. If the factor assumed for the wires is low enough, this is possible, though the breaking of one wire would in all likelihood jar the ice from the adjacent wires.

It seems probable that, theoretically at least, the factor of safety assumed for the tower is greater than that of the individual connections of the wires to the glass insulators. In this case the insulators or cross-arms would be torn off before the tower received the full load assumed in Case 3.

* This discussion (of the paper by D. W. Krellwitz, Jun. Am. Soc. C. E., printed in *Proceedings* for August, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

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COMPARISON OF RAINFALL AND RUN-OFF IN THE NORTHEASTERN UNITED STATES.

Discussion.*

By Messrs. J. C. Stevens, M. O. Leighton and F. H. Newell.

Mr. Stevens. J. C. Stevens,† Esq. (by letter).—It is very gratifying indeed to see the subject of the relation of rainfall to run-off treated so comprehensively and in such a systematic manner as in Mr. Hoyt's very timely paper. It is to be hoped that other sections of the country will speedily be taken up in a similar manner, and that all available data will be presented. Until this is done, it is doubtful if the engineering profession will come to a full realization of the almost utter futility of predicting the behavior of streams from precipitation records. Thus far, the only law which has been discovered is that a high rainfall produces a high run-off, and a low rainfall a correspondingly low run-off. "High" and "low," and "more" and "less" are about as concrete terms as one dare apply to this relation. This is not at all surprising when one considers the many factors that must be taken into account, and of which absolutely nothing is known. There is not even a notation which can express the relative values of such factors as soil conditions, topography, forestation, etc., in respect to which every drainage basin is different, but is greatly affected thereby. Taking long periods of time, a large number of well-distributed precipitation stations and reliable run-off data, it is sometimes possible to show a rather poorly defined relation, but to attempt any determination of the rate of flow, or a quantitative determination for short intervals of time, is almost absurd. Moreover, in every relation thus far determined there are always certain inconsistencies which perhaps are not

* Continued from October, 1907, *Proceedings*.

† District Hydrographer, U. S. Geol. Survey, for Washington and Oregon.

without explanation when once recognized, but their causes are so obscure as never to have warranted their prediction. In almost every Western State may be found monuments to some engineer's (not infrequently county surveyor's) misguided views on this question, in the shape of irrigation projects involved in endless litigation and expense, wholly abandoned, or necessarily abridged on account of the non-fulfillment of the predicted behavior of a stream. Mr. Stevens

Until F. H. Newell, M. Am. Soc. C. E., Director of the United States Reclamation Service, in the early Eighties, devised the method now in use of calibrating or rating a favorable cross-section of a stream by current-meter measurements, there was no inexpensive method of obtaining run-off. Since that time the method has been improved and systematized, until to-day the records of stream flow obtained by the United States Geological Survey are generally accepted as being authentic and reliable as far as it is possible to obtain them with a rational expenditure of time and money. In the West an engineer's office is incomplete without a current meter, and the methods of making measurements and preparing the data developed in the Government service are largely followed by those engineers in their private practice.

The subject of hydrography is perhaps as completely a scientific study in approximations as any with which the engineering profession has to deal. The absolute accuracy attainable in any particular case depends wholly on the amount of funds available, while the degree of accuracy required depends upon the use the data are to serve. Rarely will a subsequent variation of 10 or 15% from the basic data used prior to construction involve a plant in litigation or necessitate material alterations, while often a more liberal allowance is permissible. The demand upon the Geological Survey for run-off data all over the United States has made it necessary to include as many streams as possible in the investigations. In view of this fact it has been impracticable to adopt ultra-refined and expensive methods for general use, as their adoption would not be consistent with a rational expenditure of time and money.

For example, in the Columbia River District (Oregon and Washington), in 1906, the United States Geological Survey maintained 86 regular gauging stations where rating curves were developed by current meter. At these stations 719 discharge measurements were made, resulting in the publication of 753 monthly values of run-off. This was done at a total cost of $10 974, a cost of $127.60 per station, or only $14.60 per "monthly mean." Where conditions were favorable, the published results are probably within 10 or 12% of the truth, at others the results are approximate, while, at some, estimates were impossible. If accuracy had been the only essential, and results within 4 or 5% had been demanded, the entire appropriation would have been required for two or three stations, which would have defeated

Mr. Stevens. the entire purpose of the organization, which is that of benefiting the greatest number.

It seldom happens that the mean run-off of a stream will satisfy the engineer's demand for data, yet this is the only quantity determinable with any show of reason from precipitation records. Irrigation, municipal supply, and particularly water-power development require a knowledge of the time distribution of the various rates of flow. But it must be conceded that this feature from rainfall alone is wholly indeterminate. A single example will suffice. In Nebraska the Republican River has a drainage area of 22 000 sq. miles, and receives a mean annual rainfall of 22.12 in. The Loup River, with a drainage area of 13 540 sq. miles, receives a mean annual rainfall of 22.70 in. Winter records of run-off are not available, but 10-year means for the period from April to October, inclusive, show that the Loup discharges nearly 10% of the rainfall during that period while the Republican discharges less than 2% of the precipitation during the same time. These two river systems exist nearly side by side under practically the same climatic conditions. Neither area is forested, and the topography of each is similar. The difference in discharge is due to the difference in soil and other geologic features; yet it would have been impossible for anyone to have predicted this difference. It would have been the easiest matter in the world to have made an error of 500% in the mean open-season run-off of the Republican River, and yet this mean run-off is the only quantity susceptible of rational determination from rainfall records. Any attempt to obtain a minimum rate of flow in any other manner than by actual gaugings would be wholly absurd, for, notwithstanding the fact that the topography, climatic conditions and rainfall are practically the same for the two areas, the minimum rate of flow of the Loup River is about 1 000 cu. ft. per sec., while the Republican goes entirely dry.

Since, then, it must be admitted that the essential part of run-off data is wholly indeterminate, and that only mean annual values are at all possible from records of rainfall, is it not better to depend wholly on gaugings, especially when results sufficiently accurate for all practical purposes are obtained at such reasonable expense?

Mr. Leighton. M. O. Leighton,* Assoc. M. Am. Soc. C. E. (by letter).—The criticisms and suggestions that have appeared in response to Mr. Hoyt's paper are heartily welcomed by those who are responsible for the conduct of the investigations of the Geological Survey on the water supply resources of the United States. It is somewhat disappointing that some of the members who, in the past, have made very helpful verbal criticisms have not transmitted the same to the Society for publication in connection with this paper. Some of the criticisms that have been recorded will be utilized by the Geological Survey at

* Chief Hydrographer, U. S. Geological Survey.

once. It is well known that those who give exclusive attention to the details of any subject frequently fail to take a position far enough away to enable them to get a good perspective of the whole field, whereas those on the outside fail to take in much more than the broad perspective. This condition is made apparent in some of the discussion upon this paper, but more especially by the criticisms that have been received in times past from eminently qualified engineers. Therefore, it is only by taking into consideration both the nearer and the broader views that it can be hoped to bring the work up to its maximum efficiency. Mr. Leighton

There is no derogation in the statement that the majority of eminently qualified engineers have wondrously erroneous ideas concerning the controlling conditions in river-flow measurement. This is not surprising, because the practical measurement of stream flow involves specialization, which the engineer in broader practice cannot profitably keep in mind. This explains why the Geological Survey has received advice from unquestionably high sources which has revealed an almost complete lack of information concerning even the mechanical details of practical river-flow measurement. It is not uncommon to see reports, emanating from such sources, in which the run-off data have been refined to the third and fourth decimal place, while the methods of gauging the rivers in question have unquestionably been inaccurate by 5 and sometimes even 10 per cent. The Survey has seen engineers insist upon gauge readings down to hundredths of an inch when the chains with which the measurements were made would vary several hundredths within the ordinary range of temperature. Also, engineers have insisted upon minute accuracy in stream gauging, when, in the practical installation of power appliances, it is not possible to approach within a wide margin of such accuracy. Such incidents are to be expected, and therefore no complaint is made concerning them, and the statements are inserted here merely to call attention to the tendency.

Several of those who have taken part in the discussion have called attention to the fact that the run-off data presented in Mr. Hoyt's tables apply to so wide an area that complex conditions are presented which compensate and counteract each other and thereby obscure the real factors affecting the run-off. No one appreciates this better than Mr. Hoyt and the writer, but they are obliged to face the condition that in drawing conclusions from small drainage areas they merely accentuate the errors arising from unequal distribution of rainfall and of the effect produced on run-off by variable conditions of the land surfaces. Messrs. Frankenfield and Henry state very truly: "It is not advisable to draw hard and fast conclusions from either short periods of time or for small areas." Farther on, they say:

"It is obvious that the manner in which the rain falls, whether as a steady rain of moderate intensity, or as a heavy dash of great in-

Mr. Leighton. tensity, is of much importance in determining the relation between rainfall and run-off."

Now, it appears to the writer that the fact that Mr. Hoyt's data cover wide areas of drainage is, in a way, a distinct advantage, because local errors on either side of the line of accuracy are thereby compensated. Of course, this would not be true if there were accurate measurement of rainfall, representative of these small areas, but this would be impossible under the present appropriation of the Weather Bureau, and therefore it has been the experience of the Geological Survey that it is far nearer the truth to consider the matters over a broad area, in which local inaccuracies of reading and peculiarities of condition are merged.

There is no contention that the methods and plans of work used by the Survey are the best that could be instituted. It is freely admitted that the country would profit by a minute and detailed study of the subject on all drainage areas, large and small; but, this is impossible of accomplishment with the funds at the disposal of the Survey. The practical question, then, is as follows: Given a sum of money not sufficient to carry on the work in an ideal manner over all the country, what is the best use that can be made of it? Shall it be expended on a minute study of a few streams whereby results may be secured which shall be ideal for those particular streams, but not necessarily applicable to others; or shall the endeavor be made to secure with reasonable accuracy—as reasonable at least as the present practical demands of water development require—a system of useful data for the entire country? Take any river that has been studied by the Geological Survey, and the amount of money that has been expended in such study: To make an investigation that would conform to the ideas of some of the critics would require from twenty to thirty times the amount of money actually expended. Assume, now, that this detailed work has been accomplished, and place it side by side with that which the Survey has actually performed. The former is better, of course. It satisfies the demands of precision and gives to the engineer who has performed the work, or to the one who uses it, the comfortable and much-to-be-desired feeling of sufficiency. But, applying both sets of results to an actual power installation, of how much more value is the one than the other? Does the one enable the engineer to adjust the capacity of his wheel unit or the size of his proposed storage reservoir by a degree of efficiency that is commensurable with the difference in the cost of the work? The Survey, after studying the matter for about fifteen years, believes not.

There is another and very practical consideration in connection with the policy in this matter which oft-times escapes the engineer in practice. It should be remembered that this work is done under National appropriation, and presumably all parts of the country must

receive an equal degree of attention. If all the money were expended on a few streams, it is clear that this exclusion of the remainder of the country must continue for a long period of years, and that no data would be available except on the small proportion that is actually under study. Therefore, is it not better to present to the entire country a series of results which can be used with satisfaction, even though they be not as good as could be desired, than it is to deprive the greater part of the country of useful results? The Survey believes it is better. Mr. Leighton.

The writer is especially glad to read the discussion by Mr. Vermeule, whom he regards as one of the foremost pioneers in this line, and whose work he has long considered with admiration. Mr. Vermeule contends that it would be better to confine the work of the Survey to a number of streams and insist upon minute accuracy. There is no doubt that, if this were done, he is correct in his statement that it would do far more to "reduce hydrology to a science." In making this statement, Mr. Vermeule evidently loses sight of the fact that under the present appropriations of the Federal Government the object of the work cannot be to reduce hydrology to a science, but, on the contrary, to give to the people of the United States reasonably accurate information concerning stream-flow so that they will have something upon which to work, where before they had nothing. However praiseworthy his plan may be, it is futile to consider it with an appropriation which in the past two years has been reduced one-half.

An important matter which should be brought out in connection with Mr. Vermeule's description of his study of the relation between rainfall and run-off is his use of evaporation records. He states:

"Evaporation obeys well-known laws which have been the subject of much study and investigation, so that there is much at hand on which to base a reasonable method of computing it."

Recent, but yet unpublished, work of the United States Weather Bureau has shown that our ideas of the laws governing evaporation and the methods of estimating it are so much at variance with the truth as to make it extremely doubtful whether any of our previous work on this subject is worthy of consideration. The Weather Bureau, assisted by the United States Reclamation Service and the United States Geological Survey, is planning to devote a large amount of time and money to the most extensive investigation of evaporation that has ever been made, the seat of the experiments being the Salton Basin, in Southern California, which, as everyone knows, was recently submerged by reason of a crevasse in the Lower Colorado River. In planning for this work, it was found necessary to investigate methods, and the entire past season has been devoted to this, with results that throw doubt on nearly every feature of our past studies of evaporation. In fact, it is necessary to start work in the Salton

Mr. Leighton. Basin as though studies of this character constituted a new and untried field. Taking this into consideration, in connection with the indisputable facts concerning present inaccuracies in rainfall estimates, it is difficult to appreciate how a calculation of run-off with these two factors can be as useful as the present methods of the Geological Survey.

One word more, with regard to criticisms that have been made concerning specific stations maintained by the Survey: The fact that the Survey maintains and publishes records of any station does not commit it to any expression of belief in the accuracy of those records. It is not always possible to determine beforehand how good the records from any station may be. Sometimes it requires a full year to show whether a station is or is not worth the maintenance. In case such a station is found to be poor, the results are published merely for what they are worth, and it is the aim to give such an interpretation of them in the reports of the Survey. Other stations are established in places where it is known that the records will not be first-class, but where there is a strong demand for the best that can be produced. Strange as it may seem to those who have never gone into the details of river-station maintenance, there are many streams in the United States along the entire courses of which there is not a permanent section suitable for accurate work. The only thing that can be done under such circumstances is to produce the best possible with the funds available. With this explanation it is confidently hoped that some of those who have had occasion to criticize the Survey for the maintenance of certain stations will take all the facts into consideration, and will not grade the entire efficiency of the service on the basis of such conditions.

Mr. Newell. F. H. NEWELL,* M. AM. SOC. C. E. (by letter).—With reference to the discussion on rainfall and stream flow, there is one statement made by Mr. Thaddeus Merriman which should not go without some challenge. He states:

"In view of the differences between the results of the gaugings set forth in this paper, when compared with other and reliable long-term gaugings on other streams, and after having made careful allowances for the differences due to variable conditions on the water-sheds themselves, the speaker is of the opinion that there is sufficient evidence to indicate that the results for the run-off shown in this paper are uniformly too large, and that the discrepancy is approximately 10 per cent."

After going over the line of reasoning indicated in this statement, the writer is unable to agree with the generalization, as it apparently ignores the results of experience of many men who have devoted the best part of their lives to the building up of this work. Great care

* Director, U. S. Reclamation Service.

has been taken in securing the highest obtainable accuracy, compatible with the necessity of having, at small cost, data from widely scattered rivers. Several of the best mechanicians of the country have contributed in the effort to perfect the devices for measuring the velocity of the water. These devices have been checked again and again against other methods of obtaining the rate of flow. It is certainly a surprise to this large group of well-trained men to be told that, in spite of the many precautions taken, the results are uniformly 10% too large. Mr. Newell.

Without entering into the details of the tests which have been made, in various parts of the country, of different methods and devices used in checking the results, it is sufficient at this time to state that, among the large body of experienced men who have devoted years to work of this character, there will be found no general admission that it is in error to this degree.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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REINFORCED CONCRETE PIPE FOR CARRYING WATER UNDER PRESSURE.

Discussion.*

BY MESSRS. ERNST F. JONSON AND R. W. LESLEY.

Mr. Jonson. ERNST F. JONSON, ASSOC. M. AM. SOC. C. E. (by letter).—There is one point in Mr. Smith's interesting and timely paper which stands out as a possible problem to be solved in future attempts to build concrete pipes, namely, the fact that these pipes cracked both longitudinally and transversely.

If the water of Salt River had not contained considerable sediment, the cracking of the pipes might have been a serious matter. In many cases it might be necessary to design concrete pipes in such a way that they would not crack, partly on account of the excessive leakage due to cracks, and partly on account of the uncertainty about the durability of the reinforcement where it is intersected by cracks.

Longitudinal cracks are probably due to two principal causes:

1.—Shrinkage in the concrete, due to dryness while setting. This shrinkage causes an initial tension in the concrete, resisted by an initial compression in the steel. This tension is an addition to the stress produced by the hydrostatic pressure, so that the pipe will crack at a lower pressure than if no shrinkage had taken place.

2.—A strain in the reinforcement greater than that corresponding to the ultimate tensile strength of the concrete.

Cracks of the first kind might be prevented by keeping the concrete thoroughly wet; those of the second kind by using a very low unit stress on the reinforcement.

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* Continued from October, 1907, *Proceedings*.

Pipes constructed on the foregoing principle might have walls of considerable thickness: First, because the concrete supplies the required tensile strength more cheaply than steel, when only about one-tenth of the safe tensile strength of the latter can be utilized; second, because the leakage through concrete decreases as the thickness increases; and third, if the concrete is not to crack, there is no objection to a considerable thickness. Mr. Jonson.

The quantity of reinforcement in this case may be greatly reduced, leaving only enough to prevent failure in case the concrete should crack. For this purpose the steel might be strained up to 16 000 lb. per sq. in., or even higher.

Pipes designed on this basis, however, would not be economical for greater pressures than about 60 lb. per sq. in., which corresponds to a head of about 150 ft. When the concrete becomes too thick, in relation to the diameter of the pipe, any addition to the thickness adds very little to the strength of the pipe, because the stress decreases very rapidly toward the outside.

Transverse cracks, the author states, appeared in those parts of the pipe which were built in warm weather. They were evidently due, therefore, principally to temperature contraction. Such cracks might be avoided by leaving open contraction joints to be filled with grout in cool weather.

With regard to Table 2, the writer would make the following suggestions:

Instead of giving the leakage for the entire pipe, it probably would have been better to give the average leakage per unit of length, thus making possible an immediate comparison between the various pipes.

Instead of giving the head at the lowest point of the pipe, it would have been better to give the average head for the entire filled portion of the pipe. The leakage is a function of this average head more directly than of the head at the lowest point.

It would have been desirable to know the hour, as well as the day, when the tests were made.

It would have been interesting, also, to know the temperature of the water during the tests, as this affects the leakage on account of the variations in viscosity.

An additional column, giving the leakage per unit of length divided by the average head, would also have been of value, as showing more clearly the variation in the permeability of the concrete. The leakage may be assumed to be proportional to the head, except in the case of large cracks.

R. W. Lesley, Assoc. Am. Soc. C. E.—The author does not state the reason for constructing the pipe in the particular manner in which it was built. In Europe, for similar purposes, conduits of similar Mr. Lesley.

Mr. Lesley. capacity have been built in sections. This form of construction is by no means new, for the "Bordenave" system was used in the water supply of Venice nearly twenty-five years ago. Recently, the scientific papers seem to be quite full of descriptions of the construction of water systems with concrete pipes built according to some of the methods in use in France.

Mr. Arthur E. Collins, City Engineer of Norwich, England, who visited France to investigate the "Bonna" system of concrete pipe, for pressures up to 300 ft. head, which he was about to use on some 2½ miles of concrete main in his city, reports that he found pipes made under this process at Maison Alfort, in the Department of the Seine, such pipes having a length of 10 ft., an internal diameter of 2 ft. 7 in., and a thickness of wall of 2⅜ in. In Paris, he saw pipes of this system carrying working pressures of 150 ft. head, without oozing or other noticeable defects. A similar report was given on work at Nîmes, where ⅜ mile of pipe had been laid eleven years ago and was entirely satisfactory.

There is a high-pressure concrete water pipe of this character at Swansea, England.* The main is 3 600 ft. long and 19.7 in. in diameter, operating under a head of 185 ft. The pipe consists of an inner and an outer reinforcement separated by a sheet-steel tube and all embedded in a 1 : 2 mortar. The inner and outer reinforcements consist of longitudinal bins of cruciform (+) section wound by a spiral bar of the same section wired to them at every intersection. Only the outer reinforcement and the steel tube are considered in calculating the strength of the pipe, the inner reinforcement being considered as simply supporting the mortar.

In the *English Master Builders' Journal,* of October 2d, 1907, comment is also made as to the extent to which pipe consisting of cement with steel reinforcing rivals cast iron, on the Continent. It is stated in this case that more than 200 miles of such pipe were laid in Paris alone by the "Bonna" system. This pipe can be constructed up to 6 ft. in diameter, and is rapidly becoming an important rival of cast iron.

In Venice the pipes were 6 ft. in diameter and were joined to one another. They were made by standing upright a series of iron rings which were surrounded on the inside and outside by sheet iron. Around the rings was wound a spiral (or two or three spirals, according to the pressure to be sustained by the pipe), and this "hoop-skirt" (as one might call it) of circular rings or spirals wound round it then had concrete poured upon it between the two thicknesses of sheet iron. After the concrete had set, the sheet iron was removed. The pipe was then complete, and was laid in the trench in the ordinary way. This pipe was made under the "Bordenave" process, as already stated.

* *Engineering-Contracting*, of September 18th, 1907.

In the United States, also, a water pipe has been made by what is known as the "Phipps" system. Two concentric cylindrical shells of sheet iron are filled with a layer of cement, and another layer of cement is filled in between a removable core and the innermost sheet. These are made upright, the cement being poured between the two shells and also between the inner shell and the core. When the cement is set the core is removed, thus producing a pipe having a cement interior. These pipes have been made up to considerable sizes. Mr. Lesley.

The speaker cannot state the pressures on the Venice pipe. In the articles referred to, it will be noted that pressures up to 300 ft. have been carried. In the case described by the author there may have been some reason (not mentioned by him) that made it necessary to build the pipe in the way he describes, but the various systems of concrete pipe just referred to are well known in Europe, and have been used for many years under quite high pressures.

Another point in connection with Mr. Smith's paper is the cost of the labor on the work, but, of course, this may be well explained by the distance from civilization and the difficulty of securing good workmen. The question of cement and the difficulties found with some of it may possibly be explained, as a good deal of the material seems to have been made at the Government cement works at the Roosevelt Dam, and, according to the paper, this does not seem to have been quite as satisfactory as that first used, which came from the Denver Cement Company. In view of the fact that Los Angeles, Cal., is also about to erect a cement works of its own, for the production of the material for the new water supply, it is to be hoped that the question of a municipal or Government cement works has been thoroughly studied out by that city, before undertaking this responsibility, not only in justice to the contractors who are to use the cement, but to those people whose homes may be below the dams to be constructed with the untried material.

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THE BRACING OF TRENCHES AND TUNNELS, WITH PRACTICAL FORMULAS FOR EARTH PRESSURES.

Discussion.*

By Messrs. Horace J. Howe, C. W. Birch-Nord, Lazarus White, E. G. Haines, F. T. Llewellyn, T. Kennard Thomson, Ernst F. Jonson, Francis L. Pruyn and R. A. Shailer.

Mr. Howe. Horace J. Howe, M. Am. Soc. C. E. (by letter).—The result of a rest after disturbance is an important factor to be considered in earth pressures. This is true, whether it is a case of adhesion to a pile, or of adhesion to a row of sheet-piling. The effects of weather, water, frost, shocks, and vibrations must all be reckoned with.

In city work, the evils due to digging holes, or opening up ahead in order to show progress, are apt to be impressive where delay from various causes ensues, so that perhaps a job stands over winter or longer. Quick operation spares many a patient, and the thought persistently comes, with respect to attempts at formulating probabilities, that what might be accurate, allowable, and advisable for an energetic construction gang with a clear field and all obstacles, legal and official, removed, might be questionable when the above agencies have full play for a considerable time in a busy street.

The author sees fit to reverse the customary two-thirds height, of the authorities, and consequently increases the top relative to the

* This discussion (of the paper by J. C. Meem, M. Am. Soc. C. E., printed in *Proceedings* for August, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

bottom bracing, as shown in Fig. 7. This is a good thing to emphasize practically. One reason is that larger openings are thereby made; intermediates are not required; and buckets can have free swing when at full speed upward; but, owing to changes of cleavage of the earth, due to the above causes, the writer believes that the center of pressure will tend to travel downward, and the proportions indicated will not be preserved. The dimensions in Fig. 7 would be liberal for a pit of ordinary width, say 12 ft. Mr. Howe.

The writer had occasion once to watch a contractor who used 6 by 6-in. stuff throughout, to a depth of about 35 ft. About half way down, the bracing showed strain, and made this size about the limit, in his experience. Two lines of surface cars straddled the hole, and added substantially to the packing around the sheeting, as time went on.

The writer has seen long, straggly braces, propped up by verticals, where the author's sizes would not be adequate, and where diagonals to the ground were evidently needed.

Fig. 1, Plate LXX, gives a view at 70 ft. depth after the removal of plates in moist sand. Whether under air pressure, and for how long a time the exposure was made, is not stated. This quiescence indicates lack of pressure on the underside of a tunnel tube, and presumably on any similar foundation. Is it to be assumed, then, that nothing is gained by increased depth of foundation except greater compactness of soil?

The writer agrees that the use of the crown-bar system under a street leads to slumps, and trouble in general. Some years ago he observed an attempt made in a neighboring city by experienced contractors. The soil was reliable, but the work had to be taken out of their hands, in the interest of safety to the public. The arch system would possibly have been more successful.

In conclusion, the writer is constrained to quote the opinion of that great formularizer, Rankine, on earth pressure. He says:*

"The properties of earth with respect to adhesion and friction are so variable, that the engineer should never trust to tables or to information obtained from books to guide him in designing earthworks, when he has it in his power to obtain the necessary data either by observation of existing earthworks in the same stratum, or by experiments."

C. W. Birch-Nord, Jun. Am. Soc. C. E. (by letter).—Mr. Meem's principal statement regarding the location of the resultant of the lateral forces on retaining walls seems to be somewhat different from what most engineers have been accustomed to use in their calculations. Mr. Birch-Nord.

Does it seem reasonable that a material with a certain angle of repose will act in a manner so entirely different from water that it will change the location of the resultant of the lateral forces from $\frac{1}{3}h$ from the base to $\frac{1}{3}h$ from the top?

* "Civil Engineering," page 817.

Mr. Birch-Nord.

Does it not seem reasonable that the maximum lateral pressure per unit should be greater near the base?

Mr. J. A. Jamieson, in his valuable paper, "Grain Pressures in Deep Bins,"* shows that the maximum lateral pressure per unit occurs near the bottom of the bins.

E. P. Goodrich, M. Am. Soc. C. E., in his paper, "Lateral Earth Pressures and Related Phenomena,"† gives results similar to those obtained by Mr. Jamieson, and he goes even so far as to prove that the resultant of the lateral forces is located between $0.38h$ and $0.40h$ from the base.

Mr. Meem illustrates his method of locating the resultant of lateral pressure by assuming two triangular-shaped pieces of ice lying on top of one another, and states that the resisting force, P, should be applied at $\frac{1}{3}h$ from the top, but, by making the experiment it will be found that the force, P, may be applied at any distance above the apex and still cause equilibrium.

There are many tangled, incomplete and different ideas regarding earth pressure and its action, and it is about time that something were done, in the line of extensive experiments, either by a Special Committee of the American Society of Civil Engineers or by some of the leading universities, in order to establish the facts in reference to this matter.

Mr. White.

LAZARUS WHITE, ASSOC. M. AM. SOC. C. E. (by letter).—During the writer's connection with the work of constructing the subway through Joralemon and Fulton Streets, in Brooklyn, he has frequently discussed with Mr. Meem his theory of earth pressures, and, although at first he held more nearly to the generally accepted view of earth pressures than that advocated by Mr. Meem, he has come to believe that his general views, when applied to the pressure exerted by materials without hydraulic properties, but with at least the cohesiveness of moist sand, are more nearly true than those accepted in the design of retaining walls since the time of Rankine. However, Mr. Meem says he would not apply his methods to the designing of retaining walls.

The photographs in the paper give ocular demonstration of the fact that earth pressures do not ordinarily increase with the depth, but that, on the contrary, in undisturbed material they are almost zero at the bottom of the trench. It is with this point in view that Mr. Meem has solved so successfully numerous difficult problems in connection with the subway in Brooklyn. Along Fulton Street, in particular, a long line of buildings had to be underpinned, and the elevated railroad, trolley tracks and numerous pipes had to be supported. This work has advanced so far now, and Mr. Meem's methods

* *Transactions*, Can. Soc. C. E., Vol. XVII, p. 554; also *Engineering News*, March 10th, 1904, Vol. LI, p. 236.

† *Transactions*, Am. Soc. C. E., Vol. LIII, p. 272.

have been used on so large a scale, that it can be fairly said that his ideas and methods of sheeting have been demonstrated experimentally on a very large scale. Mr. White.

It is true, as Mr. Meem says, that sheeting and bracing used in tunnels and open excavations are usually placed by foremen in a somewhat haphazard and happy-go-lucky way. In some cases the writer has seen enormous quantities of timber used to accomplish results obtained by Mr. Meem with a much smaller quantity, designed in advance and placed carefully by his methods. In the former case, bracing foremen have been allowed to place timbers wherever they thought them necessary, with the result that the trenches were encumbered with a mass of timber which seriously handicapped the placing of steel and masonry.

It will amply repay any engineer to make careful study of Mr. Meem's paper and the methods used by him. The most severe test of his methods was at the Joralemon Street Tunnel, where the double-track subway was excavated through coarse sand, and in close proximity to various flimsy buildings, without damaging them to any serious extent. In addition, the cast-iron tubes on the Brooklyn side of the Battery Tunnels were reconstructed under his direction. Such a reconstruction is considered by the writer as a feat which has never before been attempted, but Mr. Meem's modesty prevents him from giving it the importance it deserves. There is no field of engineering where poor and slipshod methods can accomplish the waste of so much time, money and even life as that in timbering and bracing soft ground. Mr. Meem has made considerable advancement in tunneling through soft ground, and in bracing deep trenches.

E. G. Haines, Assoc. M. Am. Soc. C. E. (by letter).—This paper has proved of great interest to the writer, as he has been connected for several years with work requiring excavation in large quantities, in sheeted and open cuts, shafts, drifts, etc., and has had opportunity to observe the action of the materials under varying conditions; and, having contemplated writing a paper on the subject, he presents the substance of it now, as a discussion of Mr. Meem's paper. Mr. Haines.

Some time ago, after consulting all the available writings on the subject of earth pressure, and being unable to reconcile the results with his own observations, the writer became convinced that the common theory was erroneous, and that no practical formula could be developed by considering earth (unless either so dry or so saturated as to flow) either as a granular or as a fluid mass, but that it must be considered as a solid body, the characteristics of which it possesses.

The writer will endeavor to illustrate the result of a number of observations of "slips" or "caves," in both sheeted and open cuts, etc., and give his conclusions thereon, in the hope that they may be of some assistance in developing a practical formula for pressure.

Mr. Haines.

In excavating open cuts without sheathing, with the sides nearly or quite vertical, slips frequently occur, the form of the fracture being very uniform (for the same material), and as shown by Fig. 16.

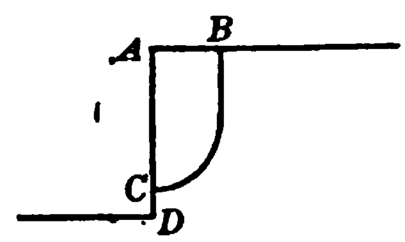

FIG. 16.

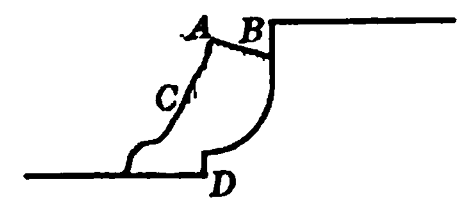

FIG. 17.

After the slide has subsided, or come to rest, it will have assumed a form such as shown by Fig. 17. The top surface, *A B,* will frequently be found inclined as shown, and quite a large volume of the material, *A B C,* quite undisturbed. The distance, *A B,* is usually about one-half *A D,* and, for any one material, keeps very closely constant.

It is very frequently noted that the toe of the fracture occurs at *C* (Fig. 16), some little height above *D,* and the writer was for some time unable to assign a reason. This will be considered later.

The plan of the slip is generally of the form shown by *A B C,* or *D B E,* in Fig. 18, while the vertical elevation of the face is as shown by Fig. 19. It may also be noted that in any material except dry sand, or in saturated ground, one may excavate to a certain depth without danger of slides; but, upon going deeper, slides are very apt to occur.

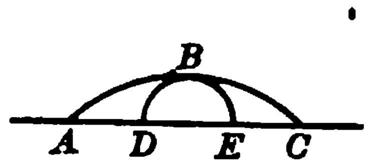

FIG. 18.

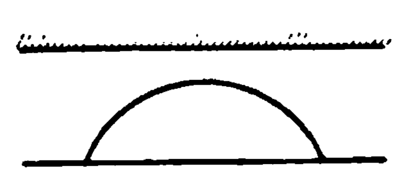

FIG. 19.

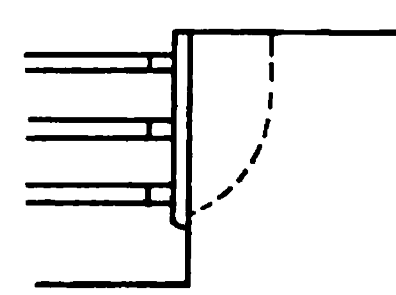

FIG. 20.

Taking next the case of a sheeted trench: It will usually be found that, for some little depth, the sheeting can be driven easily, and without evidence of much pressure. The pressure then becomes evident, and a crack appears at the surface, as shown in Fig. 20, although the line of rupture may not appear at the bottom, even if the earth is exposed below the sheeting.

Again, with sheeting driven to some depth, and kept tightly keyed and filled, a cave will often occur at the bottom, as shown by Figs. 21 and 22, if the planks are not kept well footed, and this without showing any sign of a fracture of the whole bank, at the bottom or at the surface.

Again, the surface, after the first crack (in Fig. 20), may not crack farther back, even though the excavation be continued to considerably greater depth.

In the case of a tunnel heading or drift, it is frequently found that a small drift can be driven with perfect safety; but, upon attempting to drive a larger section of the same form, in the same ma- Mr. Haines.

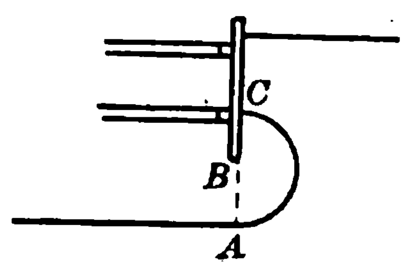

FIG. 21.

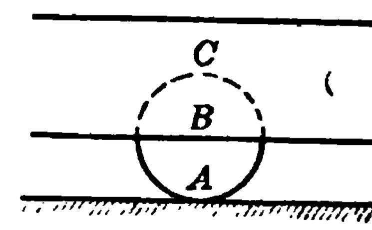

FIG. 22.

terial, falls are of frequent occurrence, and appear about as in Fig. 23.

Taking also the case of shafts or pits, it will frequently be found that a circular pit can be sunk to some little depth, without caving, in material in which a square pit or trench will cave badly, as shown by Fig. 24.

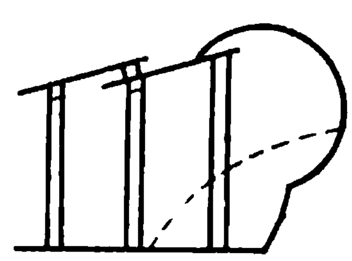

FIG. 23.

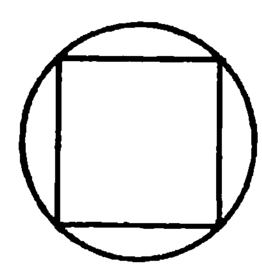

FIG. 24.

The three main classes of excavation have now been mentioned: a longitudinal trench, a horizontal drift, and a vertical pit; and, without carrying the matter further, the writer would state that in not one of these cases is there the slightest evidence of either a force similar to a hydrostatic pressure, or one similar to that required by the theory for a finely-granulated mass. After the fall occurs, other conditions remaining unchanged, no further action takes place, often for extended periods of time.

The writer has examined many falls, under all the foregoing conditions. In quite a number of them he has had occasion to take measurements, and has been impressed with one feature common to all, namely, the shape of the fracture. In nearly every case, a cross-section of the fall, in one or any direction, is in the form of a curve approximating a segment of a circle. In other words, the fractured area forms a portion of the surface of a sphere.

This fact is important. It is totally inconsistent with the theory for fluid pressure, or that for a fine granular mass; but it is perfectly consistent if the earth is considered as an elastic solid body. This assumption may properly be made, as a mass of earth in its undisturbed state possesses the same properties of cohesion, weight, tensile, compressive and shearing strength, as does a mass of sandstone, but in much less amount.

The application of this the writer will now attempt to show.

Mr. Haines. If a cube of stone, or other solid of granular structure, is submitted to compression between two parallel plane faces, it will fail, first by a shearing out of the sides, along the lines, $A\ B\ C$, Fig. 25, followed by a crushing down at B. If, instead of a cube, a slab is substituted, with the load applied as in Fig. 26, it will shear off from A to B; but, if the load be applied as in Fig. 27, and be free to move laterally, it will shear off from A to B as shown.

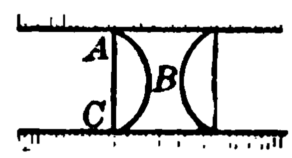

FIG. 25.

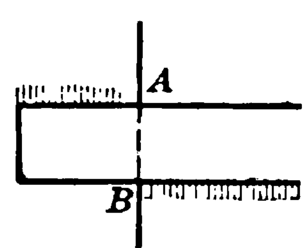

FIG. 26.

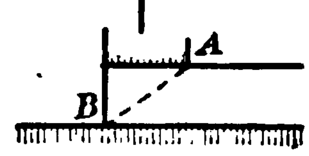

FIG. 27.

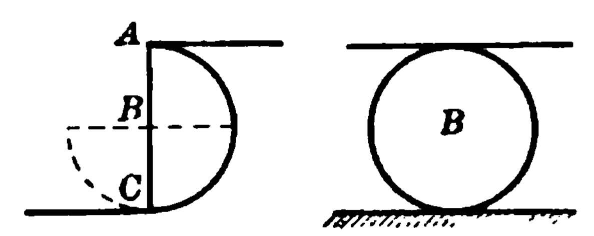

FIG. 28.

Now, this is exactly what takes place with a bank of earth, modified by the fact that such a bank must itself furnish the destructive agency, or the weight necessary to cause the shear.

It is known that the greatest area is contained within a given perimeter when it describes a circle; also, that the greatest volume is contained within a given superficial area when that area forms the surface of a sphere. Herein lies the secret of the spherical fracture. To illustrate: take a bank of earth caved as shown in Fig. 28, in section and elevation.

If $D =$ the depth, $A\ C$, in feet;
$W =$ the weight per cubic foot;
$V =$ the volume, in cubic feet;
$S =$ the shearing strength per square foot;
and $A =$ the spherical surface, in square feet;
then, at the instant the cave occurs, $W\ V = A\ S$.

Now, for a sphere, $V = D^3 \dfrac{\pi}{6}$,

and $A = D^2 \pi$.

Therefore, the weight of the volume varies as the cube of the depth, while the area varies as the square of the depth; and, W being easily obtainable, if the value of S were known, the value of D could be found at once, and thus the depth which could be excavated without any caving of the bank. This would be of no practical value, however, as S would not remain a constant, but would change under weather and other influences, in some cases reducing to nearly zero; it is important, however, in the respect that it determines the section of the

volume causing fracture, and, consequently, the pressure against any medium designed for its support. Mr. Haines.

In case the slide is very long in proportion to its height, it is simply an extension of the spherical form, caused by continued falls, the form of the cross-section remaining unchanged. It still remains a semi-circle, and explains why the crack at the top of a bank appears at a distance back equal to about one-half the depth, since the depth equals twice the radius of the curve of fracture.

In the case of an unsupported face, as in Fig. 29, the fracture does not complete the semicircle, *A B D*, but breaks out from *B* to *C*, as the distance is shorter, and, consequently, the line is one of less resistance.

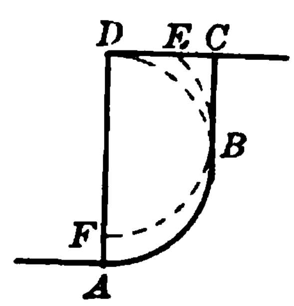

FIG. 29.

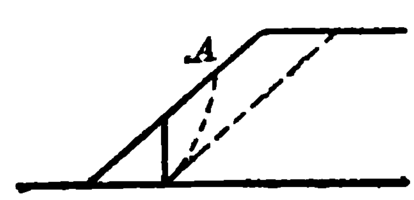

FIG. 30.

The tendency to complete the curve, however, is shown clearly in many slips by the decided overhang at the top, as at *E*; and is shown perfectly in the case of a cave at the bottom side of a sheathed trench, as in Fig. 21; the distance, *B C*, seldom being much in excess of *A B*, if the sheathing has been kept keyed tight. In short, the earth does not "fall," but shears and slides out, revolving around the point, *B*, Fig. 28; and, in an unsupported bank, the top surface will always be found on top after the slide has subsided, as was shown in Fig. 17. A cut of solid rock, if carried to sufficient depth, would act in the same manner.

A simple experiment will show the action which takes place. If, within a hemispherical cavity, there is placed a hemisphere of the same size, with its plane surface vertical (as shown again by Fig. 28), a certain pressure exerted below *B* will maintain it in its position; but, if the pressure be removed, the hemisphere will revolve until its plane surface becomes horizontal, as shown by the dotted line.

Mention has been made of the fact that the bank frequently breaks out at *F*, Fig. 29, instead of at *A*. This may be influenced by the change of the line of resistance, from *B D* to *B C*, though the writer does not now see how, but believes it to be due to the increase in the density of the material with increase of depth, and the tendency to follow the line of least resistance. It is not important, however, as the greatest area is contained within the lines, *A B C D*.

The author has presented a very simple theory, and a straight-line formula for pressure; but it appears to the writer to be defective, for the following reasons:

Mr. Haines. First.—It assumes, in effect, a material devoid of friction, which can hardly be assumed. Even in a material bearing large quantities of water, the adjoining excavation drains the excess of water, and the bank develops a large amount of frictional resistance.

Second.—The section of the bank causing pressure is not bounded by a straight line, but by a curve, as has been shown, part or all of which is a segment of a circle.

Third.—It is based on an angle of slope for the material, which is a factor not existing in a cut, but only in a fill, and then only when freshly made. The writer has frequently cut off the base of an embankment which had a well-defined angle of slope when deposited, and, although slips sometimes occurred, they did not extend to the top of the bank, but broke out as shown in Fig. 30, at A. The writer will admit that, given sufficient time, the face of an excavation would assume the same slope as would the material if placed in an embankment. It is not due to any cleavage plane in the material, however, but to the action of the elements. The surface is loosened by the rain, frost, and sun, and then water, wind, and the force of gravity move the loosened material, and pile it up at the base of the bank at its frictional angle of repose, Nature simply doing, after a long time, what Man, in forming embankments, does at once.

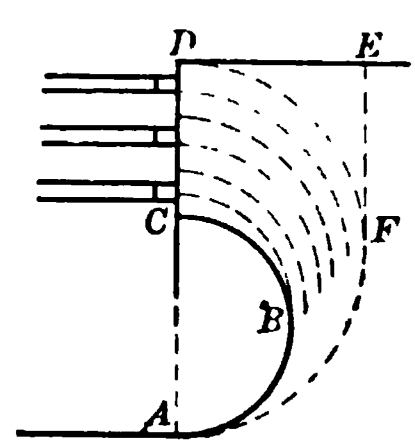

FIG. 31.

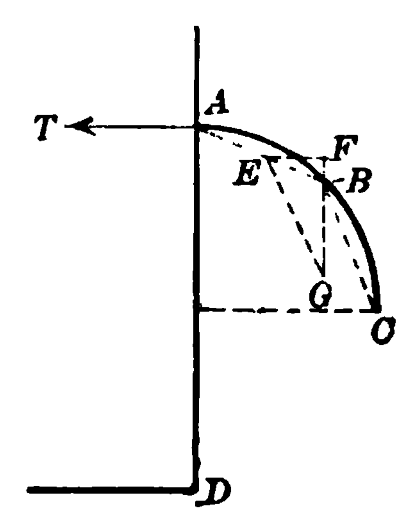

FIG. 32.

The writer recently examined a borrow-pit, on work with which he was connected fourteen years ago. The cut was about 25 ft. deep, the slope being left rough, anywhere between vertical and ¼ to 1. The material was principally sand, and the cuts of the railroad, in the same material, were sloped to 1½ to 1. Numerous slips had occurred in this bank, all showing the curved line of fracture, but a large portion of the face still stood practically intact.

It appears to the writer that the pressure against sheathing is entirely due to arch action, and that in a consideration of the curved line of fracture should be found the basis of a pressure formula.

Let Fig. 31 illustrate a sheeted cut, caved at the bottom along A B C. The volume, B C D E, forms one-half of a perfect arch with semicircular intrados, and the crown thrust is taken up by the timber-

ing and the compressive strength of the earth. This holds good for any position of the line of fracture, as shown by the dotted lines, and the arch will stand, unless the cave extend so close to the top, at *D*, that the pressure exceeds the compressive strength of the earth, or, the concentration of pressure at *B F* causes shear, or crushing of the area, *A B F*. The lines of compression must follow closely the lines of fracture, for, while the crushing value is fairly high, the value for shear is quite low, and any inclination of the compression to the fracture line would cause shear and continued falls of the material. Mr. Haines.

Considering the line of fracture to be the line of compression, the pressure at any point against the plane, *A D*, can easily be computed. This can be done graphically very quickly, as shown by Fig. 32. Let the line, *A B C*, be the center line of an arch strip of unit section, and let *L* equal its length. Also, let *W* equal the unit weight of the material. From *B* (the center of gravity of the line, *A C*) draw *B*-*G*, vertical, equal to *W L*, to some convenient scale. Completing the triangle of forces, *E*-*G* and *B*-*E* are equal to the resultant of the forces at *C* and *A*, respectively; and *E*-*F* is equal to the horizontal component of *B*-*E*, or, the horizontal pressure at $A = T$.

Assuming, for purposes of comparison, that $W = 1$, and solving for *T* at different heights, a series of coefficients is obtained, which, if multiplied by the actual value of *W* for any case, equals the pressure for that height. This is shown in Fig. 33, by the line, *A*, as well as the same factor for the author's method (assuming a natural slope of $1\frac{1}{2}$ to 1), and the common theory for hydrostatic pressure, by the line, *C*.

The area, *D E F*, Fig. 31, however, has not yet been considered. This section, directly, cannot cause any pressure at *D*, because its area at that point is zero. Indirectly, however, it does exert a pressure along the whole height, *A D*, due to its dead weight, this pressure being zero at *A*, and a maximum at *D*. The total amount of arch thrust from this area can be found by taking *F* as a center of moments and computing the thrust at *D*. The writer believes this to be distributed, varying uniformly from *A* to *D*, and, converting its value to the form of a triangle, and adding to the line, *A*, in Fig. 33, the line, *D*, is obtained, giving the total coefficient of *W* and the unit pressure at any height.

It will be noticed that this line gives pressures about half as great as those by the author's formula, and the writer believes that these are more nearly correct. He has never seen anything to indicate the extreme pressures shown by the author's formula, and Mr. Meem states that it is seldom necessary to use timbers as large as required by that formula.

Since the value of any theory depends upon its application to different conditions, the results, by the one proposed by the writer, will

Mr. Haines. be compared with the conditions found in practice in widely different cases.

Taking first a shaft: If the material be fairly uniform, and the shaft can be excavated to a depth equal to its clear width without falls, there is little danger of falls at greater depth, and the reason is not hard to find. Let *A B C D*, Fig. 34, be such a shaft. If a hemisphere, described on any side, be not heavy enough to cause shear over its surface, there is little danger of a larger fall (as shown by the dotted line), for it would then also have to crush a ring of the material, as at *D E*. The pressure likely to be found, then, at any depth, is due to local falls, and is equal to the arch thrust, shown on Fig. 33, for a height equal to the width of the shaft.

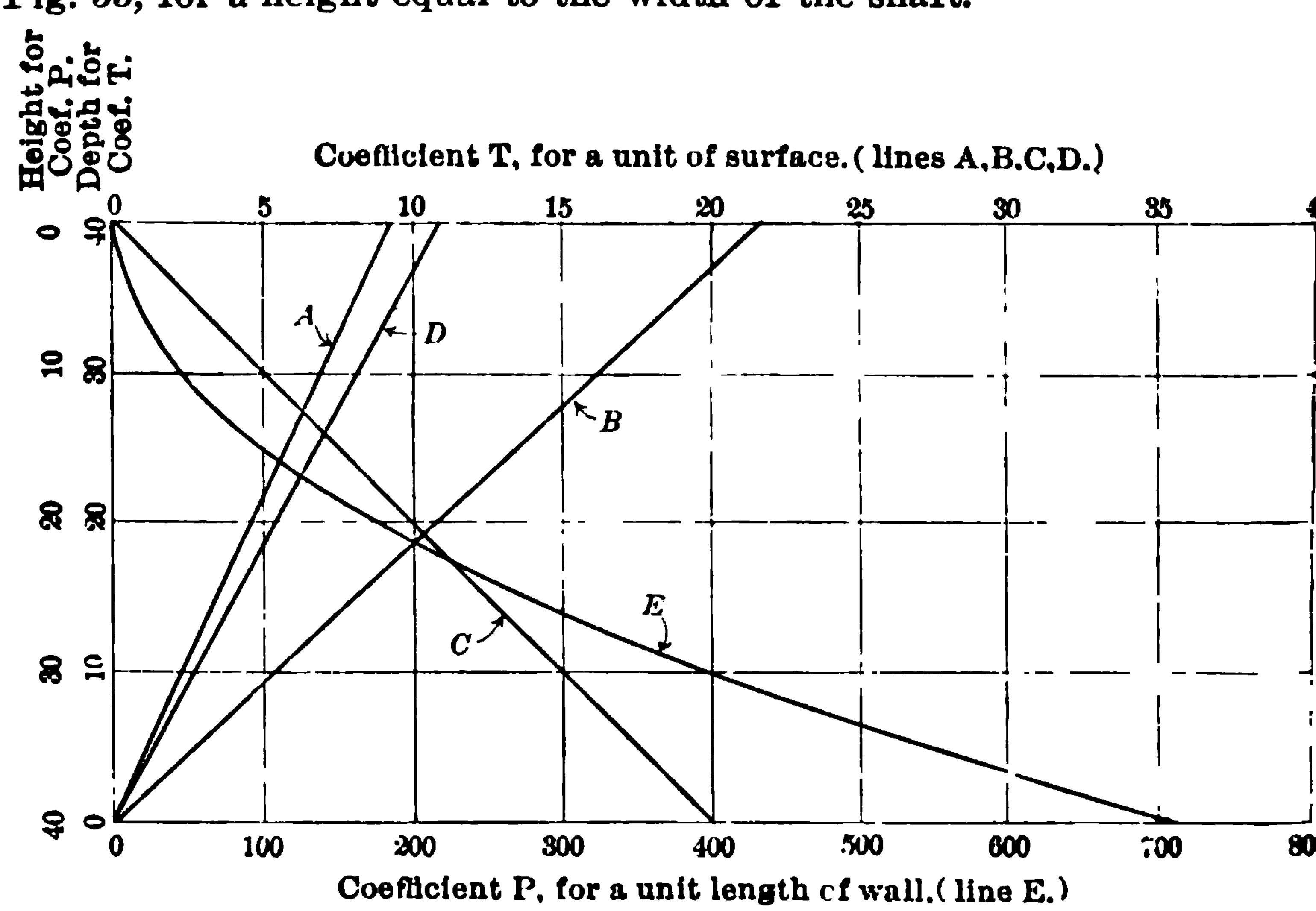

FIG. 33.

Fig. 34 also shows why a circular shaft is the safest form, as the hemisphere of dangerous weight has already been removed on each side, and the earth can fail only by the crushing of the material.

The writer, a few years ago, watched with considerable interest the excavation, in moist sand, of a well, about 8 ft. in diameter, without the use of sheathing. After the excavation had proceeded a few feet a wooden templet was placed, and an 8-in. brick lining was built to the surface. From that time forward the excavation proceeded by cutting under the templet, and the bricklaying was continued at the top, until, when last seen by the writer, a depth of 55 ft. had been reached. There was no evidence of crowding, or pressure, and the ring sunk readily, although the excavated material took a slope of about 1½ to 1. The foreman stated that he had often used this method for much greater depths.

Mr. Haines.

Taking also the case of tunnel drifts in ordinary material, as shown by Fig. 35: If the sides, only, were of solid rock, a fall might be expected, as shown by the semicircle, *A B C*. Also, if the roof, only, were of rock, a cave might be expected, as shown by *A D E*. In abandoned mine workings, where falls are of frequent occurrence, the writer has found these conditions fulfilled, the earth seldom breaking back of the supporting rock, at *A* and *C*, and the height at *B* (unless the spherical surface be broken by boulders) not exceeding one-half *A C*, even though considerable water be flowing. In the case of a drift in clear earth, however, the timbering cannot be kept in perfect contact with the earth, and after the portions, *A B C A* and *A D E A*, have moved, there remains the section, *A B D A*, without support, except its cohesive strength, and it falls.

Thus it is seen that in firm ground the section causing pressure on a drift is described, from *F* on the axis of the drift, by a semicircle, with a radius equal to one-half the sum of the height and width, and completed by two quadrants, described from *G* and *H*, with a radius equal to one-half the height. Now, as to the actual pressures: The pressure against the cap, *B C*, Fig. 36, is due to the dead weight of the volume, *A B C D*, and varies as the ordinates between the lines, *A D* and *B C*.

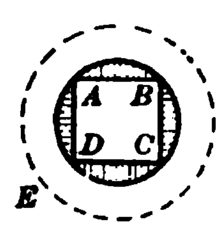

FIG. 34.

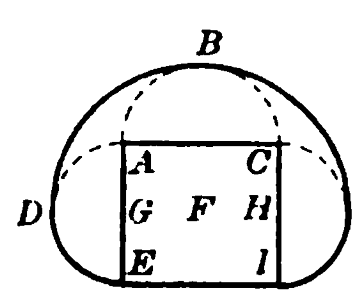

FIG. 35.

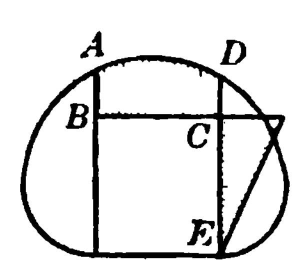

FIG. 36.

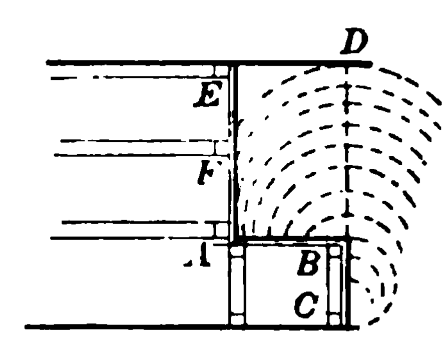

FIG. 37.

The pressure against the side, *D E*, however, does not vary as the ordinates to the curve, but is due to the arching action of the material, as shown by the line, *A*, Fig. 33; and it is probable that most of the total pressure for the height, *D E*, is concentrated against the height, *C E*, as shown.

That the pressure at *C* is far in excess of that at *E* is shown clearly in practice by the fact that it is always necessary to strut between the top of the legs of the bents (unless they be mitered, or entered into the caps), while at the bottom they rest simply on a mud-sill.

Considering next the case of open cuts: The author has mentioned the case where it may be necessary to undercut the side of a sheeted trench, as shown by Fig. 37, and the writer recently saw such a case, the work being done by the author with perfect success. After the cut had been carried to about 20 ft. in depth, it was found necessary to excavate a gallery, about 200 ft. long, 5 ft. high and 7 or 8 ft. wide, along the side of the cut at the bottom. This was done by using

Mr. Haines. poling boards from A to B, supporting them on wall-plates and posts, and by short vertical sheeting from B to C. This gallery was under a street carrying a double-track trolley line and heavy wagon traffic, and tremors from nearby elevated railroad structures could be plainly felt. The material was compact gravelly loam, with some small boulders. There was absolutely no evidence of any pressure against $B\ C$, the earth being exposed sometimes for several feet, and the plank placed by hand. There was some evidence of load on the poling boards from A to B, but nothing like the full weight of the material above them. There was evidence of considerable load on the posts at A, however, and also a considerable thrust, laterally, on the timbers, A, E, and F, as shown by the fact that points given on the timbers, for use in the construction, moved from 1 to 2 in. This is exactly what might be expected from the arching of the material, as, the axis of the arch being on the line, $C\ D$, there is both a horizontal and vertical component to the thrust against the sheeting, as shown by the curved lines of thrust.

Thus far, the writer has confined his examples to what may be termed stable material. He will now go further, and say that it applies equally well to any material.

Taking first the case of dry sand: In the work of the Atlantic Avenue Improvement, in Brooklyn, of which the writer was Resident Engineer of a division, it was necessary to excavate a trench about 1½ miles long, 35 ft. wide, and about 25 ft. deep. On each side of the cut was a line of railroad track, carrying locomotives and heavy traffic, the center of the tracks being in some cases only 6 ft. from the sheeting. On one side of the cut, 20 in. from the sheeting, there was also a 48-in. water main under pressure.

The contractor, wishing to withdraw as much of the sheeting as possible, placed it in two lengths. The top part was composed of 18 or 20-ft. planks, and the lower part was pieced out with 1¼-in. planks, set about 1 ft. in the ground at the bottom, and held at the top (from 5 to 7 ft. above) by cleats nailed to the under side of the bottom rangers. The material varied greatly, but in sections it consisted of sand so clean and fine that it filtered through the cracks in the sheeting and piled up at the bottom. A worse set of conditions could hardly be conceived, yet none of these light boards failed, nor did they show signs of great pressure, although 6 by 10-in. rangers cracked, near the top of the cut, in a number of cases. By referring to Fig. 38, the reason will be made clear. If a vessel be filled with fine sand, and an opening be made in the side, as shown at A, the sand will not flow out unless the height of the opening exceeds two-thirds of the thickness of the wall; but, if a larger opening be made, as at B, the sand will flow and pile up until its angle of slope reaches the top of the opening, and no more will then flow out. Within the vessel, the action

still goes on; the sand falls from the bottom of the arch, and piles up at the bottom, until it finally breaks out at the top. This is purely an arching action, the falling material serving to support the base of the arch and building up a new arch as it is deposited, the lines of pressure being more clearly shown by Fig. 39. Mr. Haines.

The writer traced the line of first crack, on both sides of the work just mentioned, in the block paving of the street, for nearly the entire length of the work, and the ratio of width to depth appeared to be entirely independent of the character of the material; and, although the railroad track was sometimes within and sometimes without the fractured area, the first crack appeared very closely at a distance back equal to one-half the depth of the cut.

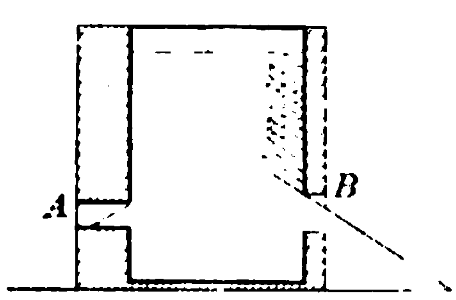

FIG. 38.

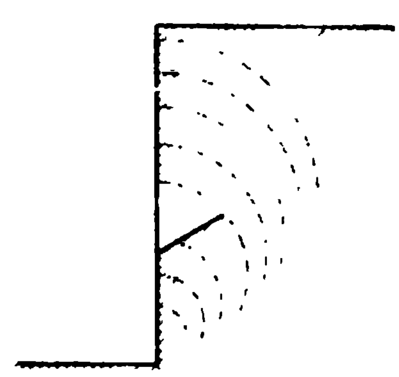

FIG. 39.

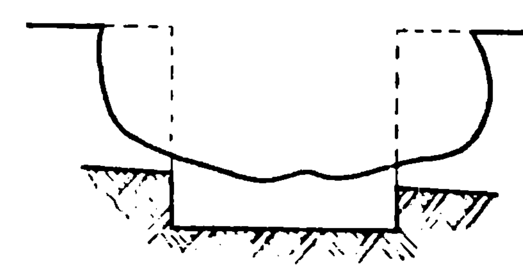

FIG. 40.

Turning now to saturated material: In the construction of a section of subway, in New York City, a trench was excavated about 45 ft. wide and 35 ft. deep, through ground which at some time had been filled into tidal water. The top surface of the ground was 7 ft. above mean high water, and the water appeared at that depth in the excavation, and constant pumping was necessary. The excavated material was so soft that it would slop out of the buckets, and the laborers had to work in rubber boots. The sheet-piling was driven by a pile driver, and the bottom 5 to 8 ft. of the cut was in rock. After the excavation was complete, a crack, about 2 in. wide, appeared at a distance back somewhat less than half the depth to the rock. It became evident that the timbering was under some stress near the top, but it would have held safely had it not been for an unfortunate accident which destroyed the timbering, and the cut caved in, on one side for about 60 ft. in length, and somewhat less on the other. The material from these slips assumed such a flat slope that the two sides met in the bottom of the cut, and piled up as shown by Fig. 40, leaving exposed a height of about 20 ft. of the cave on one side. The top overhung the face, 8 ft. below, by nearly 3 ft., notwithstanding the fact that the base of a large pile of rock was within 6 ft. of the edge, and part of the footing for a stiff-leg derrick was actually beyond the exposed face below. It was several days before all the timbers could be replaced, and the slide refilled, yet it stood in this condition. The writer had a number of measurements taken, and, all things con-

Mr. Haines. sidered, it was the finest example of the spherical fracture he has ever seen.

A mass of saturated earth closely resembles a mass of wet concrete, and Plate CX is a photograph, showing a cave in the latter material, due to insufficient bracing of the forms. The thickness of the wall was 3 ft., and the cave extended 4 ft. deep, the top being disturbed for about 2 ft. back from the form. The disturbed portion was all within the line drawn on the photograph, and the vertical face of the fracture is clearly shown at *A*. The portion marked *B* slightly overhung the fracture below. The concrete was placed quite wet, and none of it had been placed more than an hour, so that it could hardly be said to have set.

Taking, then, the design of a coffer-dam, with sheet-piling driven to some depth, as at *C*, Fig. 41 (*a*): As the water is pumped down, there is a uniformly increasing pressure against the sheet-piling, as shown by Fig. 41 (*b*). Below the level of the point, *B*, the material may be in either one or two conditions, which may be termed water filled with earth, or, earth filled with water. In the first case, the material is what is called mud; it is not a fluid, nor does it act as one. It is insoluble mineral matter, and its presence in the fluid does not increase the density of the fluid, or its hydrostatic pressure, any more than it would if the grains were widely separated, and at points away from the sheeting. The water forms a perfect film against the sheeting, the same as it would in a box filled with billiard balls; and the pressure diagram for the water extends to the bottom at *C*, as shown by the triangle, *E F G*. The volume of earth, *B C D*, also exerts a pressure against the sheeting, in the same manner as dry sand. The water leaking through the sheet-piling, or under the bottom, however, carries with it some of the earth, and tends to destroy the arch; and, unless more material be added, to allow it to rebuild itself, and the sheet-piling be kept well footed below the limits of the excavation, the arch will be entirely destroyed, and the unbalanced pressure from the other side will move the dam and cause its destruction. Thus there is, in this case, the arch pressure for the height, *B C*, added to the hydrostatic pressure, as shown by *G H I*. The amount of the pressure, however, is reduced by the buoyant effect of the water, and the value of *W* to be used with the coefficient is the difference between the weight of the water and the earth.

The second condition mentioned—that of earth filled with water—covers such material as shale, some clays, compact earth, and gravel. This material, while it passes water freely, somewhat resembles a series of screens, all made of wire of the same size, but of different mesh, the finer mesh being at the top, and increasing in size downward. This applies to a large number of materials, the finer and more compact material having been deposited at the top, and the writer

PLATE CX.
PAPERS, AM. SOC. C. E.
NOVEMBER, 1907.
HAINES ON
EARTH PRESSURES AND BRACING.

Cave in Mass of Wet Concrete, Due to Insufficient Bracing.

has often produced this effect artificially by a covering of clay, a canvas mat, straw and manure, chaff, etc. Mr. Haines.

In this case, the pumping tends to remove the water faster than it can enter at the surface of the earth, and prevents any hydrostatic pressure below *B*. The water-pressure diagram is shown by *A B E*, in Fig. 41 (*c*). Below the point, *B*, there is the arch pressure due to the earth, but it is also carrying the weight of the column of water, shown by *A B D J* in Fig. 41 (*a*), and, in determining the factor, *W*, to use with the coefficient, it must be included in the weight of the earth, *B C D*, in Fig. 41 (*a*). The pressure diagram, then, is completed by the triangle, *B C D*, and, if the depth of the water be very great, the pressure below *B*, for a distance, may even exceed that due to the hydrostatic pressure, as shown by the dotted line, *C F*.

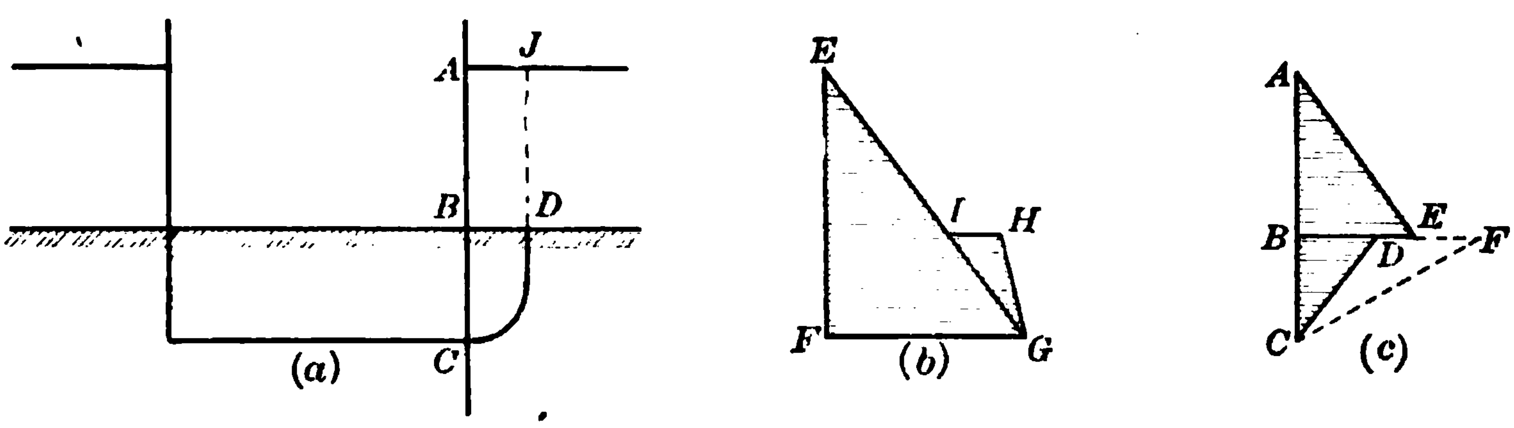

FIG. 41.

In subaqueous tunnel work, with a shield, and under air pressure, there obtains, probably, the worst set of conditions. Let Fig. 42 represent such a case. Here, there are peculiar conditions. If the air pressure is made equal to the head of water at the top of the tube, water will enter below that point, while, if the pressure be made great enough to keep out the water at the bottom, the air will escape rapidly above that point. Either of these things tends to destroy the arching effect of the earth. A common practice is to keep the pressure about equal to the head of water at the center of the tube, and allow some water to enter. This causes softening of the material, with consequent settlement, and the whole mass probably settles down along the lines, *A B C*. The excess of air pressure at the top causes erosion of the material, and "blow-outs" occur, followed by a reduction of air pressure. This reduction of pressure causes a rush of material toward the tube, and partially restores the arch just destroyed. That the disturbance is purely local is shown by the fact that a relatively small amount of clay, dumped in the water, is sufficient to close the break, and allow work to proceed which would not be the case if one considered the angle of slope at which the material would stand.

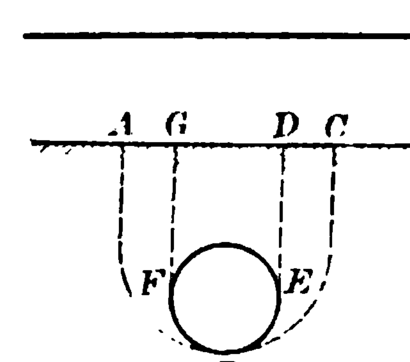

FIG. 42.

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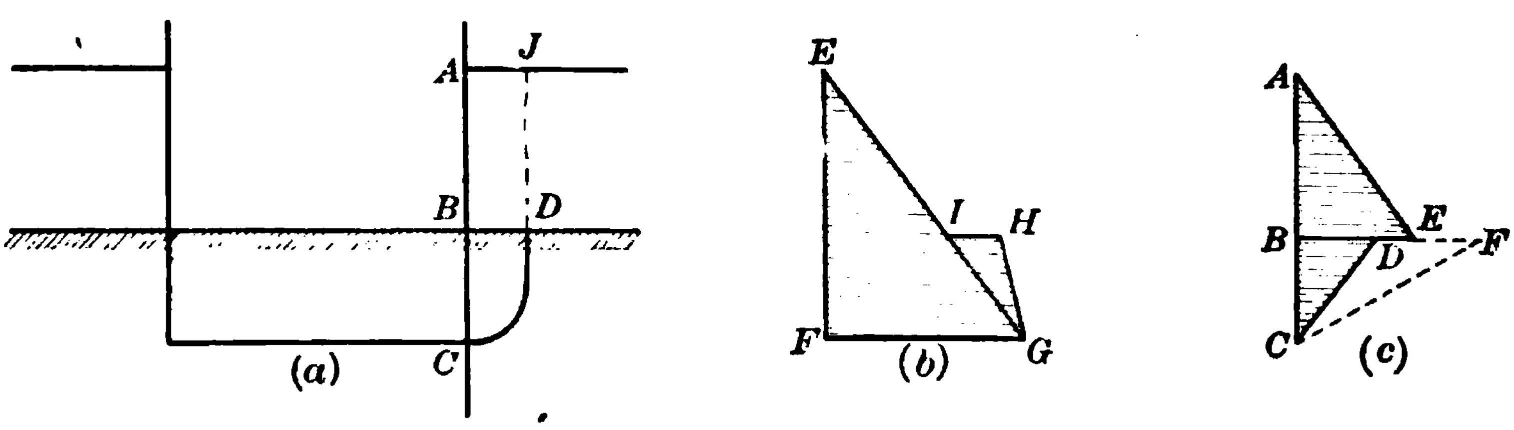

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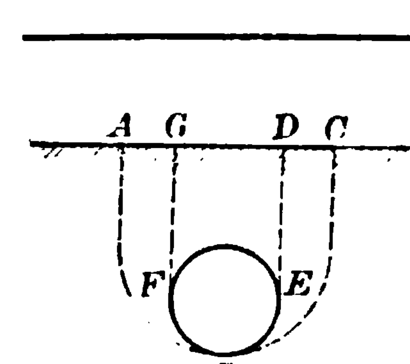

FIG. 42.

Mr. Haines. along a horizontal plane from *B*, and this toe is well removed from the fracture line, *C D*. To overturn the wall, also, from the arch action, it would not only have to lift the volume of earth, *C E F G*, but also shear the full height, *C E*, unless the soil fails by compression at *B*, which is possible, and should be considered in the design.

The writer believes there is but one case where it is impossible to compute the maximum pressure against a retaining wall, and that is where the material is stratified and sloping toward the wall. If the material be water-bearing, and overlying rock, or clay, it breaks away and moves toward the wall; and if the volume which would thus move, and the slope of the strata, could be determined in advance, then the maximum pressure could be determined. But these breaks often occur several hundred feet back, and the writer has known the break to occur even 1 000 ft. up the slope.

In practice, the conditions for maximum pressure do not often exist, but they should be considered. They exist sometimes, and the wall fails, this being usually attributed to faulty foundations, which is a rather poor excuse and cannot often be proved.

There is no little literature on the subject of earth pressures, but the writer has found most of it of little value, being in most cases flatly contradicted by experience. Almost without exception, it is based either on Coulomb's theory of a wedge of greatest pressure—which the writer ventures to assert does not apply to material of granular structure—or, on a hydrostatic fluid with a weight equal to earth. This, the writer contends, cannot apply, because, the material being insoluble, in order that it may act as a fluid, it becomes necessary that each particle be carried in suspension by the water; but, in order to do this, its weight must reduce to that of the water, and the hydrostatic pressure becomes that of water only.

A paper* presented before the Institution of Civil Engineers by the late Sir Benjamin Baker, Hon. M. Am. Soc. C. E., contains the results of a number of experiments, and, what is of more value, descriptions of walls which stood, and walls which failed, together with the conditions existing. The writer has found in this paper nothing directly contradictory to his theory, but much tending to confirm it.

In reference to the cracks on some 34 miles of deep-timbered trenches and tunnels, Sir Benjamin Baker stated that, on each side:

"The slope of these fissures was so uniformly at the angle of ½ to 1, measuring from the bottom of the excavation, that the resident engineer professed to be able to foretell with certainty where a building or fence wall, standing over the tunnel, would crack most."

He also stated:

"Assuming this ½ to 1 to represent Coulomb's line of least resistance, then the natural slope of repose of the material would appear to be 1⅓ to 1, which is considerably steeper than what it was in fact."

* *Minutes of Proceedings*, Inst. C. E., Vol. LXV, p. 140.

Trautwine, also, has called attention to the fact that some walls show bulging at about one-third the height, and that all walls tend to become vertical in spite of the batter. Neither of these facts can be reasonably explained by Coulomb's wedge of greatest pressure, or by a hydrostatic theory. Mr. Haines.

A few years ago, the writer built a retaining wall which failed; but, by all the existing theories, it should have stood. This wall was a bridge abutment at a river crossing. It was about 25 ft. high, and was founded on solid rock. The base was 42% of the height, and the face had a batter of 1 in. per foot. The wall had a section in the form of a triangle, with the apex 1 ft. above the back-fill. The parapet behind the bridge seat was 20 in. thick, and the back line was brought vertically down to an intersection with the triangle. The masonry was of cut stone, in courses from 30 to 16 in. thick, laid in cement mortar, and most of it in Flemish bond. The back-fill was placed in horizontal layers, by wheel-scrapers. This abutment stood perfectly for six months, until subjected to a 10-ft. rise of the stream, when a crack appeared in the bank, at a distance back somewhat less than half the height. The wall was checked up, and found to have moved outward 4 in., but it did not then incline outward. One week later the base was in the same position, but the top inclined 8 in. outward from its original plane, and some of the courses were shoved outward.

It seemed evident to the writer that the softening of the bank by the water had caused shear and movement of the wall, followed by the arching action of the dry material above and the overturning of the wall. This abutment was torn down, and rebuilt with a base of 50% of the height. In tearing down the wall, and removing the back-fill, the crack in the bank, with the characteristic curved fracture, could be traced nearly to the bottom, and no support was given the bank either during the removal or rebuilding of the abutment. As soon as completed and the back-fill replaced, the bridge was erected, and the writer has always been puzzled to know whether that abutment was actually holding up the bridge, or the bridge holding up the abutment, and also, by what line of reasoning the responsible parties arrived at the conclusion that a wall, which had failed utterly with a base of 42% of the height, would be safe (with a reasonable factor of safety) if the base were increased to 50% of the height.

In presenting this theory, which is believed to be new, the writer would state that, while the matter has long been in his mind, its actual preparation has been made rather hurriedly.

He would also call attention to the fact that the theory makes use of but two factors, namely, the weight of the earth, which can always be obtained, and the curved line of fracture, which he has observed so many times as to lead him to believe that it follows a natural law, as he has attempted to show.

Mr. Haines. Since writing the foregoing discussion, the writer's attention has been called to an article in *Engineering News*,* by Mr. A. A. Steel, describing the apparatus used, and the results of some experiments on earth pressures.

The apparatus was of a size larger than usual, and was designed to test the pressures at different points in the height of a bank of earth. The results are interesting, and the following is abstracted from Mr. Steel's description:

"The diagram * * * gives the results of the experiments with damp earth. It will be seen that the pressure against the upper measuring board increases much more rapidly than that against the lower one. For this reason the series was discontinued shortly after the upper balances indicated a greater pressure than the lower ones. It was supposed that this was due to the earth clinging to the sides of the pit, like the sand in a molder's flask, and not settling freely. To avoid this the cohesion was destroyed by spreading the earth upon an asphalt pavement. Here, by the aid of convenient draft it was completely dried in about two weeks.

"The experiments were repeated with this dry earth, but again the pressure on the lower boards was less. This series of experiments required two days' time, and during the night the tangential component of the pressure on the upper board fell off about 60 lbs. This might have been due to a readjustment in the mass of the earth, but it seemed probable that it might have been caused by some meddlesome boy. To get a check on this and the difference in the pressure of the two boards, the series was repeated exactly, and a laborer engaged so that it could be finished in one day. The drop did not again appear * * *."

The point to which the writer would call attention is the fact that Mr. Steel had here a perfect example of the arching of loose material, for, the material being thrown in loose, the compression of the bottom material by the weight above it, and the friction of the mass settling against the boards, threw the upper portion into action as an arch, and, had the experiment been continued, some very valuable results might have been obtained.

As it is, his paper is a striking example of the extent to which one is governed by precedent, for, his apparatus being designed to accord with Coulomb's theory of a plane of rupture, his mind was unable to accept any results inconsistent with that theory, and the experiments were stopped.

Until investigators can bring themselves to make their deductions from observed facts, and not try and make the facts fit some predetermined conclusion, no really valuable results in any line can be obtained.

In conclusion, the writer thinks that the thanks of this Society are due Mr. Meem, for his paper; and, while he does not agree with

* Vol. XLII, p. 261, October 19th, 1899.

the author's theory for pressure, he believes him to be perfectly right, in the case of sheeting, in placing the base of his pressure triangle at the top, instead of at the bottom. The writer also has the greatest respect for the author's system of timbering, for, from personal observation, he can state that it performs perfectly the functions for which it is designed, while some, at least, designed in accordance with the common theories, fails utterly, and more of it shows stresses far in excess of those for which it was designed. **Mr. Haines.**

F. T. LLEWELLYN, M. AM. SOC. C. E.—This paper seems to be a very practical and valuable contribution to the scanty literature on this subject. **Mr. Llewellyn.**

It is a subject with which the speaker is not very familiar, but, during the last twelve months, having had occasion to investigate the strength of mine timbers, he has found voluminous literature telling how to frame the ends of timbers, but hardly anything suggestive of a method of calculating their stresses.

The speaker believes that in the anthracite coal regions there are some practical "rules-of-thumb" (they can hardly be called formulas) in use by the mine foremen for computing the sizes of timbering at a depth of 500 or 1 000 ft., although these rules are largely modified by personal judgment. It is interesting to note that the one most commonly used in Eastern Pennsylvania is in the line with Mr. Meem's theory, although applied to depths very much greater than those in the trenches he mentions. This rule is as follows: In order to determine the safe distance between the rooms in an anthracite coal mine, it is calculated that the distance from center to center of rooms should be 1% of the distance below the surface of the ground plus five times the thickness of the overlying seams, the whole to be divided by two.

The main point of interest is that this formula contains two elements, the first being a function of the total depth, and comparatively insignificant, while the second, being a function of the thickness of the overlying seam, is the main factor, which would seem to support Mr. Meem's theory that the pressure does not increase at any rate in direct proportion to the total depth.

It has been stated that it was unfortunate that there had been practically no large tests of lateral pressures on pilings in trenches and elsewhere, and the speaker desires to state that the company with which he is connected is now arranging to conduct a somewhat extensive series of experiments in driving steel sheet-piling, and excavating to a depth of 50 ft. At present he cannot say what arrangements will be made for the dissemination of this information, but is satisfied that the results will be presented to the engineering profession as fully as possible.

T. KENNARD THOMSON, M. AM. SOC. C. E.—The author gives a formula, for calculating the strains on the bracing for open cuts or **Mr. Thomson.**

Mr. Thomson. trenches, based on the angle of repose of the material, but he does not state how to find this angle, and, at the best, it could only be guessed at, for, while it would be easy to ascertain the angle for any loose material after it had been removed from the trench, it would seem to be impossible to determine it in advance of the excavation, as every foot underground is likely to disclose new conditions. Again, this assumed angle only holds good for dry material, as the author states, but there are very few cases of excavation where underground streams are not encountered; and water mains are likely to burst, and even a thunderstorm is apt to cause disastrous results.

It is quite true that it is sometimes safe to remove the bottom braces; in fact, the speaker has dug pits for elevated foundations in Brooklyn from 12 to 15 ft. deep without any bracing at all, but they were immediately filled with concrete, and, although no difficulty was experienced, it is not an example to be followed, even in Brooklyn, and certainly not in New Jersey.

In good hardpan, under air pressure, the speaker has excavated a depth of from 27 to 30 ft. without any bracing, but in many cases it would be suicidal to do this. Most New Yorkers must have seen banks of quicksand from which the water has been drained standing with a perfectly vertical face, and, when in this condition, of course, there would be no strain whatever on the bracing, and yet a slight disturbance would cause, and has caused, such banks to collapse without warning, and the daily papers have reported many cases of this kind where laborers have lost their lives.

It is quite true, as the author states, that there are many cases where his formula would not apply, so the only excuse for this discussion is the fear that some young engineer may overlook the exceptions and design his bracing by the formula, guessing at the angle of repose.

The experienced man will probably prefer to rely on his own judgment, as every case has to be studied by itself, and the more one has to do with earth or water pressures the more respect he has for their power and the less liberty he takes with them. There is probably not an experienced foundation man in the country who has not seen coffer-dam bracing collapse, sometimes at the bottom, sometimes half way up, and elsewhere.

In discussing fluid pressure, the author doubts if the full hydrostatic pressure would be found at the bottom. This is a subject which has been before the speaker for many years, in connection with deep cellars. He has put in cellar floors from 16 to 32 ft. below water, and the conclusion is that in some cases the full pressure does not occur, in many it does, while in others the pressure is much greater than the hydrostatic head would call for.

In pneumatic caissons in quicksand in New York City, where the

caissons are sunk with as little disturbance of the ground as possible, it is found necessary to keep the air pressure almost exactly at the theoretical water pressure. Many want to calculate the pressure at from 90 to 100 lb. per cu. ft., including the weight of water and sand. Mr. Thomson.

The speaker has seen a coffer-dam of 8-in. tongued and grooved sheet-piling driven several feet below the excavation before the digging started, braced with 12 by 12-in. walings, 5 ft. apart vertically at the top and less than 3 ft. apart vertically at the bottom, with 12 by 12-in. struts 6 ft. apart horizontally, and 30 ft. deep, where the waling deflected as a beam, the struts crushed 2 in. into the posts, and the timbers were pretty nearly knocked into kindling wood, the bottom caving in 2 or 3 ft.

Again, on the Canadian Pacific Railway in the Rockies, in 1885, there was a "clay" tunnel, high and dry, which was apparently all right until it was completed with heavy timber lining, when it suddenly shut up. Another effort was made, and 12 by 12-in. bracing was put in continuously instead of at intervals, and, as this tunnel also collapsed after completion, the company abandoned it and did not try again for more than 20 years, when another location was selected.

In open coffer-dam work, it is often better to use larger timbers spaced further apart than smaller sizes spaced closer, as more working room is left.

What the author refers to as sheet-piling has, in a great many cases, superseded the old-fashioned sheeting, as it is much better where it can be used, especially if the ground is wet or treacherous.

Ernst F. Jonson, Assoc. M. Am. Soc. C. E. (by letter).—This paper introduces a new problem in the theory of earth pressure, by calling attention to the fact that the accepted theory cannot be applied to all cases, especially to those in which cohesion becomes an element in the stability of a mass of earth. Mr. Jonson.

It would be well if the author's empirical formula of earth pressure on sheet-piling could be verified by some more definite data than general experience, such as measurements of the stresses in the braces. This might be done by inserting hydraulic jacks with attached gauges, at the lower ends of the braces.

The author's simile of a wedge action seems to be unfortunate. If the pressure of an embankment were of this nature, and the pressure on a unit length of sheet-piling were $P = \frac{w\ h^2 \tan. c}{2}$, then, according to the same reasoning, the pressure on the upper half of the sheet-piling would be $P = \frac{w\ h^2 \tan. c}{8}$. Hence, it is seen that the average pressure on the upper half is one-half of the average pressure on the entire height of the sheet-piling. This implies that the pres-

has often produced this effect artificially by a covering of clay, a canvas mat, straw and manure, chaff, etc. Mr. Haines.

In this case, the pumping tends to remove the water faster than it can enter at the surface of the earth, and prevents any hydrostatic pressure below *B*. The water-pressure diagram is shown by *A B E*, in Fig. 41 (*c*). Below the point, *B*, there is the arch pressure due to the earth, but it is also carrying the weight of the column of water, shown by *A B D J* in Fig. 41 (*a*), and, in determining the factor, *W*, to use with the coefficient, it must be included in the weight of the earth, *B C D*, in Fig. 41 (*a*). The pressure diagram, then, is completed by the triangle, *B C D*, and, if the depth of the water be very great, the pressure below *B*, for a distance, may even exceed that due to the hydrostatic pressure, as shown by the dotted line, *C F*.

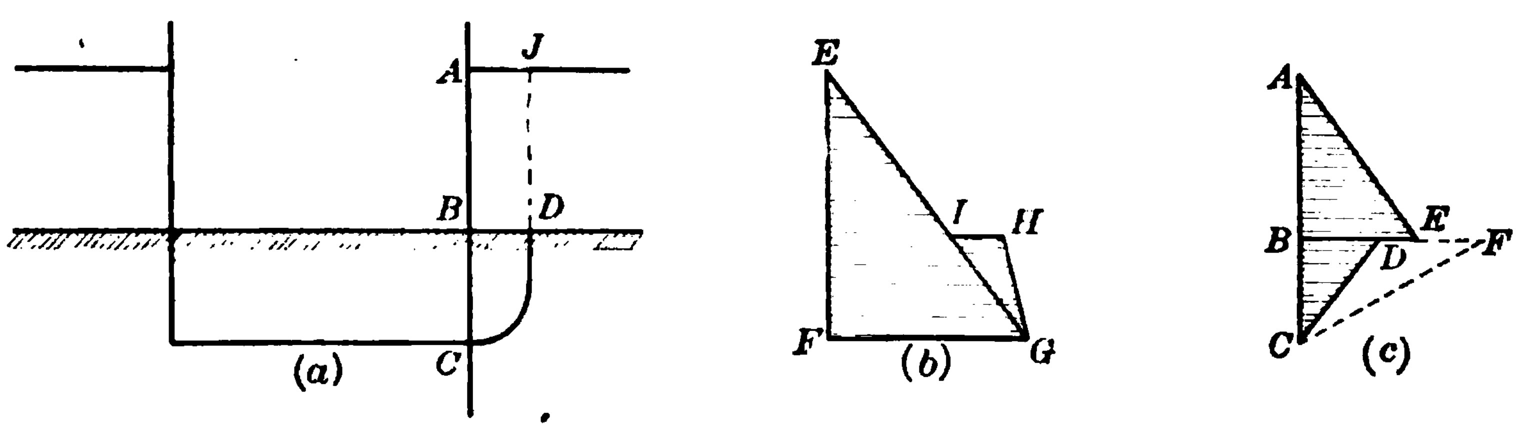

FIG. 41.

In subaqueous tunnel work, with a shield, and under air pressure, there obtains, probably, the worst set of conditions. Let Fig. 42 represent such a case. Here, there are peculiar conditions. If the air pressure is made equal to the head of water at the top of the tube, water will enter below that point, while, if the pressure be made great enough to keep out the water at the bottom, the air will escape rapidly above that point. Either of these things tends to destroy the arching effect of the earth. A common practice is to keep the pressure about equal to the head of water at the center of the tube, and allow some water to enter. This causes softening of the material, with consequent settlement, and the whole mass probably settles down along the lines, *A B C*. The excess of air pressure at the top causes erosion of the material, and "blow-outs" occur, followed by a reduction of air pressure. This reduction of pressure causes a rush of material toward the tube, and partially restores the arch just destroyed. That the disturbance is purely local is shown by the fact that a relatively small amount of clay, dumped in the water, is sufficient to close the break, and allow work to proceed which would not be the case if one considered the angle of slope at which the material would stand.

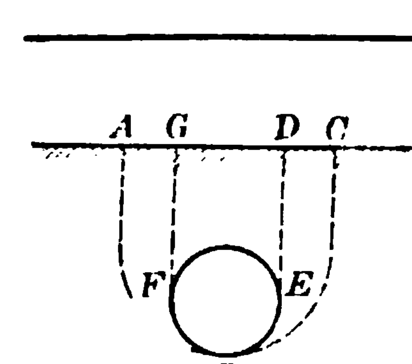

FIG. 42.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

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PAPERS AND DISCUSSIONS.

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WATER PURIFICATION AT ST. LOUIS, MO.

Discussion.*

BY MESSRS. PHILIP BURGESS AND EDWARD PRINCE.

Mr. Burgess. PHILIP BURGESS, ASSOC. M. AM. SOC. C. E. (by letter).—The writer has been engaged for the last year and a half in making tests of the various water purification plants in Ohio, for the State Board of Health, and has read with much interest Mr. Wall's paper on the design and operation of the St. Louis plant. There are, however, two or three points in the operation of this plant which differ from the method ordinarily used at filter plants, and are not discussed in the paper. Among these is the practice of using such large amounts of lime, with a consequent reduction in the hardness of the treated water.

It is stated in the paper that the amount of lime used is as much as the water will stand, and that lime is added until the water in the last basin is slightly caustic. This means that, while the river water contains generally two or three parts of carbon dioxide per million, and hence no normal carbonates, all the free and half-bound carbon dioxide is eliminated by the treatment, producing a water that contains only normal carbonates and, at times, even a slight caustic alkalinity. The question arises: is the use of a large amount of lime necessary for proper coagulation? The chemical reactions, as stated in the paper, show a reduction of the bicarbonates by the treatment, and the use of lime in amounts beyond that necessary for the removal of the acid iron salts formed by addition of the copperas solution to the raw water.

* This discussion (of the paper by Edward E. Wall, M. Am. Soc. C. E., printed in *Proceedings* for September, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

The following statement gives the results of the reactions of the coagulants in those filter plants in Ohio where copperas and lime are used as coagulants. There is first a reaction of the copperas on the raw water, before lime is added, causing a reduction of the bi-carbonate alkalinity and the formation of acid iron salts. Lime is then added to neutralize the iron salts, and the total alkalinity is brought back to about the original content of the raw water. A further increase in the amount of lime added gives an increase in the amount of total alkalinity, a condition which obtains until a point is reached at which a softening action by the lime begins. Beyond this point the further addition of lime results in the decrease of the total alkalinity, a reduction varying with the amount of lime used, and similar to that at all water-softening plants. The amount of normal carbonate present before there is any softening action has, in the winter, been found to be as high as 32 parts per million even 6 hours after the coagulants had been added. Mr. Burgess.

In many filter plants where lime and copperas are used as coagulants, it is the custom to add first the copperas and then the lime until a sufficient quantity of the latter is present to give a treated water which is slightly alkaline to phenolphthalein. In general, it may be said that the use of 1.0 gr. of copperas per gallon requires 0.4 gr. of lime per gallon (in bulk) to give a water containing a small amount of normal carbonates. Whether or not there is a final reduction of the total alkalinity of the treated water, seems to depend on the character of the raw water, its temperature, and somewhat on the time which elapses between the introduction of the coagulants.

At Marietta, Ohio, there is a filter plant using lime and iron for coagulants, where very careful records of the operation of the filter plant are kept; the results there are characteristic of those at similar plants where lime and iron are used. Table 7 shows the monthly averages of the daily determinations made during the last 6 months by Mr. George M. Gadsby, who has been retained as chemist at the plant.

The most striking feature of Table 7 is the great variations in the bacterial efficiencies obtained by the basins, namely, from 50 to 94.4 per cent. The operation of the plant was somewhat hindered during March by the very high stage of water in the Ohio River, which resulted in a decrease in the efficiency of the coagulating basins, but the chief cause of the poor results obtained during March and April was that not quite sufficient lime was used. The necessity of having the water slightly alkaline to phenolphthalein was not appreciated, and the effluent from the filters was frequently slightly acid to phenolphthalein. It should be noted, however, that practically no iron went through the filters, even under this condition. Beginning on May 1st, more attention was paid to having a small amount of normal

Mr. Burgess.

TABLE 7.—ANALYSES OF RAW WATER AND EFFLUENT FROM FILTERS, MARIETTA, OHIO.

(Parts per Million.)

	MARCH.		APRIL.		MAY.		JUNE.		JULY.		AUGUST.		AVERAGE.	
	Raw.	Eff.	Raw.	Eff.	Raw.	Eff.	Raw.	Eff.	Raw.	Eff.	Raw.	Eff.	Raw.	Eff.
Turbidity	300	0	175	0	220	0	170	0	1 500	0	250	0	435	0
Color	6	8	6	6	10	6	18	15	18	15	10	8	10.5	9.7
Total alkalinity	17	21	18	20	22	27	25	30	30	33	28	31	23	27
Phenol alkalinity	0	0	0	0	0	+2	0	+3	0	+2.5	0	+3*	0	+1
Incrustants	33	42	35	46	21	34	19	32	20	42	43	55	28	42
Total hardness	50	63	53	66	43	61	44	62	50	75	71	86	52	69
Calcium	....	....	18	23	15	20	15	24	21	31	27	34	19	26
Iron	....	....	0.05	0.08	0.11	0.06	0.11	0.11	0.10	0.09	0.06	0.05	0.09	0.08
Copperas, in grains per gallon	3.38		1.17		2.06		2.14		3.25		1.65		2.27	
Lime, in grains per gallon	0.95		0.82		0.88		0.85		1.23		0.67		0.89	
Bacterial efficiency of coagulating basins	50.0%		67.4%		87.8%		80.6%		94.4%		84.8%		77.5%	

* Estimated.

Raw water contains from 2 to 4 parts per million of free carbon dioxide. Length of period of sedimentation = 3.5 hours.

carbonates in the treated water, with the result that the efficiency of the basins increased immediately to nearly 90 per cent. In other words, the use of a very few more pounds of lime increased the efficiency 20 per cent. Mr. Burgess.

The tendency to use the least possible amount of lime was not due to inadvertence, but to the fact that previously, when lime was used in such quantities as to give 20 to 40 parts of normal carbonates per million in the treated water, the air pipes in the filters were clogged by lime incrustants and had to be removed and cleaned. It was with the intention of avoiding a recurrence of this condition that the least possible amount of lime was used.

At Lorain, Ohio, lime and copperas have been used as coagulants in the old purification plant since 1903. Lime is generally used in such quantities as will give a small amount of normal carbonate in the effluent, but the occasional use of too large amounts of lime, where the coagulation period is only 20 min., has caused the formation of after-deposits of lime on the grains of the sand, resulting in an increase in the effective size from 0.52 to 0.61 mm. By analysis, the sand in the filters was found to be covered with lime to the extent of 37% of its weight. It is manifestly impossible to obtain satisfactory results from the filters under such conditions. It has been stated that a rapid application of wash-water tends to remove these after-deposits of lime, but the writer has no definite information on this point.

From the foregoing facts, it is apparent that the proper use of lime and copperas, as coagulants for filtration, requires a constant and accurate adjustment between these two materials, such that the treated water shall contain a small, and only a small, amount of normal carbonates. Under such conditions, there is caused an increase in the total hardness of the water, amounting to about ½ gr. per gal. for each grain of copperas added, accompanied by slight change in the temporary hardness and a removal of about 33% of the color. It will appear, also, that in the lime and copperas treatment, as applied at St. Louis, not only is the coagulation obtained from the copperas, but the treatment is one of softening the water. The coagulating masses formed by the softening treatment are large, flocculent, and very efficient in the removal of suspended matters and bacteria; and to this is probably due much of the success of the plant at St. Louis. Also, the large removal of color at St. Louis is undoubtedly due to the softening treatment, without which probably only one-third of the dissolved color would be eliminated.

The use of such large quantities of lime, where sedimentation and clarification alone are relied on for the purification of the supply, is shown to be necessary at such plants as that at St. Louis; but, from the foregoing discussion, it would seem to be shown that this practice is not advisable in connection with the coagulation of water applied to filter plants, on account of the clogging of the sand and pipes by after-deposits.

Mr. Prince. EDWARD PRINCE, M. AM. SOC. C. E. (by letter).—No one can read this interesting and instructive paper without a feeling of satisfaction at the recital of efforts ending in success so well earned.

In 1846 the writer first knew St. Louis water, when, on his way to college, he visited his brother, David Prince, M.D., Professor in Pope's College, whose office was at the corner of Fourth and Olive Streets (then the heart of the city). It was the habit of Dr. Prince to draw two buckets of muddy water from his faucet, at about 6 P. M., and set them away to settle over night, say 12 hours. The next day he would use the rather milky-looking water for drinking and lavation. This was the general custom, and few used a strainer of any kind, although thousands of acres of excellent tripoli existed in untold quantities in Missouri. Some few people—laundrymen, and others—used a little alum to clear the water over night, for rinsing clothes on the following day. About $\frac{3}{8}$ in. of jelly-like mud was deposited at the bottom of the clear-water buckets after 12 hours' subsidence. The popular opinion then was that the Missouri mud was very healthful, and promoted good digestion.

The St. Louis water also possessed another excellent quality, as proven by the fact that the United States Navy sent to St. Louis for quantities of Missouri River water for use on long cruises, and particularly for use on the voyages in the South Atlantic, because this water never soured nor turned to bilge-water aboard ship, as most waters would.

When the writer was building the water-works at Quincy, Ill., in 1873, and operating them in subsequent years, he became very well acquainted with the late Thomas J. Whitman, M. Am. Soc. C. E., then Chief Engineer of the St. Louis Water-works, and at one time an honored Vice-President of this Society.

Several times Mr. Whitman showed the writer the subsiding reservoirs in operation. At that time there were four of these basins, each of 16 000 000 gal. capacity, or about a day's supply in all.

The quantity of silt deposited seemed to be enormous, and, of course, this deposit had to be removed. These subsiding reservoirs, as remembered by the writer, were constructed of cut stone, with vertical sides on the water faces, and as shown in Plate LXXXII, and in each, at 1, 2, 3, and 4, as shown by a double line, there was a sluice, about 5 ft. wide and 1 ft. deep, having a gentle slope and communicating with a sewer running to the river. The outside of the bottom of each reservoir was a little higher than the sluice at any point, and the slope was probably about 1 in 100.

To get rid of the deposit was a serious problem. Mr. Whitman tried all probable ways, such as the use of hose nozzles, solid and spray, large and small, with powerful pumps, but in vain. The jets simply honeycombed the, say, 10 or 12 in. of thick, caked, jelly-like mud.

He finally adopted the following simple method: The reservoir to be cleaned was drained, and, commencing at the upper end, a sufficient number of men were provided with stout-handled push-boards, say 10 or 12 in. wide, and 2 or 3 ft. long, probably with one light steel edge for cutting, and it was really surprising to see these men move to the sluice so easily such large cakes of silt. Then, the water let in at the sides, for the purpose of lubrication only, completed the transportation to the river. Considering the condition of the silt, after several weeks of settlement and compacting, this, no doubt, was the best way to clean out the reservoir and get rid of the deposit at the least cost. Mr. Prince.

It is interesting and remarkable that, at the intake, Chain of Rocks, St. Louis gets its water mostly from the Missouri River, although the two rivers unite several miles above this point. After the Missouri River (often called The Big Muddy) empties into the Mississippi, the waters do not commingle, and, usually, the line of demarcation can be seen, by the difference in the color (turbidity) of the two rivers, for miles below the city. This and many of the foregoing remarks have been made simply to emphasize the fact that it was a great problem at St. Louis to obtain clear water economically, and in great quantity, from water holding so much solid matter in suspension.

Some credit, also, is due to Mr. Charles R. Henderson, former Superintendent of the Quincy Water-works, for first having found out the proper proportions of chemicals to use in the process of water coagulation and subsidence resulting in clear water. He is now connected with the water-works at Waterloo, Iowa, and has exerted himself very cheerfully to impart all the information gleaned from very long continued and carefully made experiments.

The methods and appliances in use and to be brought into use in St. Louis for the purification of the water are the results of persistent study and experiment. They are quite an advance on the Quincy methods, in many respects, and seem to be very complete.

It is possible, however, that some cheaper coagulant may be discovered, which will dispense with the use of sulphate of iron; and yet, at the present time, sulphate of iron as a coagulant and lime (water or milk) as a precipitant have no successful rivals for water-works purposes.

It is likely that the addition of subsiding reservoirs Nos. 7 and 8 will be found to be worth very much more than they will cost, for obvious reasons. With the evidently rapid growth of St. Louis, it is likely that still more subsiding reservoirs, and possibly the enlargement of the intake at Chain of Rocks, will become necessary and desirable.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

ALBERT JOHNSTONE CAMPBELL, Assoc. M. Am. Soc. C. E.*

DIED MARCH 23D, 1907.

Albert Johnstone Campbell was born at Stoke, England, on December 7th, 1854, and was the last survivor of the ancient family of Glen Saddel. As lineal heir of the Earls of Crawford and Lindsay, he was claimant to the dormant Earldoms of Annandale and Hartfield.

After being educated at Rugby, he entered the Royal School of Mines, passing successively through the Chemical, Metallurgical, Geological and Physical Sections, and being awarded the Associateship of Mines in 1876. The next four years were spent in the study of practical mining and engineering in Cornwall and Spain, and in 1880 he was appointed General Manager of the Trojes and Anjangeo Silver Mines and Smelting Company, in the State of Michoacan, Mexico, which position he held for three years, carrying out the successful development of the mines, and introducing many improvements in the system of smelting and general organization of the works.

In 1883, Mr. Campbell joined Mr. H. V. Rudston Read in a partnership, as Consulting and Constructive Engineers, with a branch establishment in Mexico, and, while in that country, carried out many important engineering works, for the Mexican Government and by private contracts, amounting to many millions of dollars. The principal work, and the one with which Mr. Campbell's name will always be associated, was the construction of the Tequixquiac Tunnel for the drainage of the Valley of Mexico, the length of the tunnel being 6¼ miles—at that time the longest tunnel in existence.

The splendid organization and ability displayed by Mr. Campbell in carrying through this work in the face of the greatest difficulties was recognized officially by the President and Government of Mexico, and, at a later date, the Committee of the Chicago Exhibition presented Mr. Campbell's firm with a gold medal as some recognition of the magnitude and importance of the work, and of the skillful engineering displayed in its performance. Also, in conjunction with his partner, he built the Mexican Southern Railway, which was the first railway in Mexico to cross the Sierra Madre Mountains, and, up to that date (1892), was the only railway in Mexico which had been completed from the start with permanent work in every detail. The time allowed for the construction of this road was ten years, but it was

* Memoir prepared by F. W. Abbot, M. Am. Soc. C. E.

completed in three years, and a bonus of $1 800 000 was earned on that account. The railroad was fully ballasted, with all masonry, culverts, bridges, etc., in position. One-third of this line is probably one of the heaviest pieces of railroad work on the North American Continent, 60 miles of it being constructed in a cañon with 4% grades. In its construction it was necessary to build 150 miles of side-roads to carry in supplies to the 8 000 men employed on the work.

The characteristic zeal and energy with which Mr. Campbell threw himself into these and other works in which he was engaged while in Mexico led to the serious undermining of his health; in fact, the illness which necessitated the operation from which he subsequently died, was directly traceable to the fevers contracted twenty years before in the Mexican swamps.

Mr. Campbell was elected an Associate Member of the American Society of Civil Engineers on May 2d, 1894. He was also a Member of the Institution of Mechanical Engineers, a Member of the Institution of Civil Engineers, and an Associate of the Royal School of Mines.

JOSEPH WILLIAM ZIPPERLEIN, Assoc. Am. Soc. C. E.*

Died July 22d, 1907.

Joseph William Zipperlein, born in Philadelphia, Pennsylvania, on February 13th, 1870, was the youngest son of Charles and Louisa Zipperlein. He attended the public schools of Philadelphia until 17 years old, when he left school to accept a position in the publishing house of Lea Brothers. After about one year's service he resigned, to begin, in November, 1888, his career in the cement business, entering the employ of the Commercial Wood and Cement Company as stenographer, from which position he gradually advanced to that of Secretary in 1891. At this time he withdrew from the company in order to become identified with The William G. Hartranft Cement Company, as Vice-President, a position which he held continuously until his death.

Mr. Zipperlein was closely identified with the development of the American Portland cement industry, being a pioneer salesman, not only in the United States, but also in Canada; and, in the latter country, he has been financially interested in the cement industry since 1898.

Mr. Zipperlein was beloved by all who knew him. He was of modest disposition, amiable, tactful, a staunch friend, and a thoroughly honorable business man. Quiet and even tempered, honest in all his

* Memoir prepared by Richard L. Humphrey, M. Am. Soc. C. E.

dealings, resourceful in his work, he commanded, not only the entire confidence and respect of his business associates, but of his employees as well.

In the summer of 1906 sickness forced him to go abroad, and, although the trip proved beneficial, he never fully regained his health, but suffered almost continuously until his death, on July 22d, 1907.

He was elected an Associate of the American Society of Civil Engineers on June 4th, 1901. A large number of friends and acquaintances mourn his untimely death.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852.)

VOL. XXXIII. No. 10.

DECEMBER, 1907.

Edited by the Secretary, under the direction of the Committee on Publications.

Reprints from this publication, which is copyrighted, may be made on condition that the full title of Paper, name of Author, page reference, and date of presentation to the Society, are given.

CONTENTS.

NEW YORK 1907.

Entered according to Act of Congress, by the American Society of Civil Engineers, in the office of the Librarian of Congress, at Washington.

American Society of Civil Engineers.

OFFICERS FOR 1907.

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Vice-Presidents.

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BERNARD R. GREEN.

Term expires January, 1909:
JOHN A. BENSEL.
JOHN A. OCKERSON.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOSEPH M. KNAP.

Directors.

Term expires January, 1908:
AUSTIN L. BOWMAN,
MORRIS R. SHERRERD,
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Term expires January, 1909:
GEORGE GIBBS,
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Term expires January, 1910:
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JAMES CHRISTIE,
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ARTHUR L. ADAMS.

Assistant Secretary, T. J. McMINN.

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THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

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Special Committees.

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ON RAIL SECTIONS:—Joseph T. Richards, C. W. Buchholz, E. C. Carter, S. M. Felton, Robert W. Hunt, John D. Isaacs, Richard Montfort, H. G. Prout, Percival Roberts, Jr., George E. Thackray, Edmund K. Turner, William R. Webster.

ON CONCRETE AND REINFORCED CONCRETE:—C. C. Schneider, J. E. Greiner, W. K. Hatt, Olaf Hoff, Richard L. Humphrey, Robert W. Lesley, J. W. Schaub, Emil Swensson, A. N. Talbot, J. R. Worcester.

ON STATUS OF METRIC SYSTEM:—Stacy B. Opdyke, Jr., John Waterhouse, D. A. Molitor.

ON ENGINEERING EDUCATION:—Desmond FitzGerald, Benjamin M. Harrod, Onward Bates, D. W. Mead, Charles Hansel.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER......................5918 Columbus.
CABLE ADDRESS........................"Ceas, New York."

Vol. XXXIII. DECEMBER, 1907. No. 10.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

November 20th, 1907.—The meeting was called to order at 8.30 P. M.; Director A. L. Bowman in the chair; Chas. Warren Hunt, Secretary; and present, also, 200 members, and 66 guests.

A paper by William H. Burr, M. Am. Soc. C. E., entitled "The Reinforced Concrete Work of the McGraw Building," was presented by the author. Written communications on the subject from Messrs. H. F. Tucker, W. J. Douglas, Carl Gayler, J. A. Jamieson, T. L. Condron and F. F. Sinks, were presented by the Secretary. The paper was discussed orally by Messrs. E. P. Goodrich, Walter M. Smith, Guy B. Waite, E. W. Stern, and the author.

The Secretary announced the death of PAUL ERNEST OBERNDORF, elected Junior, February 5th, 1907; died November 9th, 1907.

Adjourned.

December 4th, 1907.—The meeting was called to order at 8.30 P. M.; Director A. L. Bowman in the chair; Chas. Warrent Hunt, Secretary; and present, also, 79 members, and 19 guests.

The minutes of the meetings of October 16th and November 6th, 1907, were adopted as printed in the November number of *Proceedings*.

A paper by Owen B. French, M. Am. Soc. C. E., entitled "Invar (Nickel-Steel) Tapes on the Measurement of Six Primary Base Lines," was presented by John F. Hayford, M. Am. Soc. C. E. Written communications on the subject from Messrs. J. A. Ockerson and Horace Andrews were presented by the Secretary, and the paper was discussed orally by Messrs. H. J. Howe, Charles Macdonald, Noah Cummings, C. E. Trout, and J. F. Hayford.

Ballots for membership were canvassed, and the following candidates elected:

AS MEMBERS.

ALEXANDER LESLIE BLACK, New Orleans, La.
FRANCIS BLOSSOM, New York City.
WILLIAM CHARLES BOYD, Pittsburg, Pa.
GEORGE ROBERT GRAHAM CONWAY, Monterey, Mexico.
SAMUEL FORDER CRECELIUS, Louisville, Ky.
LORING NELSON FARNUM, New York City.
JAMES BOWMAN GOODWIN, McCall Ferry, Pa.
RALPH HADLOCK OBER, Vulcan, Wash.
UMESABURO OGAWA, Kyoto, Japan.
EDWARD JONES PEARSON, Seattle, Wash.
JULIUS PITZMAN, St. Louis, Mo.
HENRY SOUTHER, Hartford, Conn.
CHARLES COKER WILSON, Columbia, S. C.

AS ASSOCIATE MEMBERS.

MANDAYAM ANANTHAMPILLAI ANANTHALWAR,
Channapatna, Mysore, India.
CHARLES NOBLE BENNETT, Charleroi, Pa.
JOSEPH ALEXANDER DONAHEY, Darrowville, Ohio.
THEODORE CHRISTIAN FISCHER, Elizabeth, N. J.
JOHN CLYDE FRUIT, Chicago, Ill.
HARRY TODD GRISWOLD, New York City.
AUGUST FREDERICK HARTMAN, New York City.
HENRY PEREZ HOYT, Millinocket, Me.
CHARLES WILSON KILLAM, Boston, Mass.
EARLE KELLY KNIGHT, Camagüey, Cuba.
MAURICE JOSEPH LEAHY, Hamilton, Ohio.

ROBERT JAMES MIDDLETON, Ottumwa, Iowa.
RAY MURRAY, Poughkeepsie, N. Y.
CHARLES HENRY QUIMBY, JR., Mt. Vernon, N. Y.
JULIAN PIERRE WILLIAM RICHMOND, New York City.
RALPH HAMILTON STEARNS, New York City.
GEORGE SYKES, New York City.
HOWARD EDWARD VAN NESS, Little Falls, N. J.
SAMUEL JUDSON VAN ORNUM, Pasadena, Cal.
EDWARD BEAUMONT WARDLE, New York City.
HENRY WRIGHT WOODCOCK, Brooklyn, N. Y.
ALBERT MENGER ZABRISKIE, Plainfield, N. J.

The Secretary announced:

The transfer of the following candidates by the Board of Direction on December 3d, 1907:

FROM ASSOCIATE MEMBER TO MEMBER.

WILLIAM HOYT BALCH, Boston, Mass.
THOMAS JENKS CARLILE, Jamaica, N. Y.
ROBERT HAWXHURST, JR., Antofagasta, Chili.
LEON SOLOMON MOISSEIFF, New York City.
WILLIFORD HARRY TERRELL, Clyde, N. C.
HENRY ARTHUR VAN ALSTYNE, New York City.

The election of the following candidates by the Board of Direction:

AS JUNIORS.

On October 1st, 1907:

NATHAN BENEDICT, Bocas del Toro, Panama.

On November 5th, 1907:

WILLIAM ALFRED LAMB,. Sacramento, Cal.
FULTON PACE, Caldwell, Idaho.

On December 3d, 1907:

CHARLES FREDERICK BREITZKE, New York City.
HERBERT EDWARD CANTWELL, Albany, N. Y.
HENRY HELM CLAYTON, Amarillo, Tex.
EDGERTON CHESTER GARVIN, Washington, D. C.
IRVING DEAN GOODWIN, Ann Arbor, Mich.
WILFRED LEWIS, Dubuque, Iowa.
HENRY WARNER MAYNARD, Seattle, Wash.

The Secretary announced the following deaths:

ABRAHAM BEEKMAN COX, elected Member, April 1st, 1874; died February, 1906.

EDWARD ADINO HANDY, elected Member, January 2d, 1889; died November 21st, 1907.

GEORGE THOMAS NELLES, elected Member, October 3d, 1888; died November 15th, 1907.

B. C. RUMSEY, elected Fellow, May 12th, 1870; date of death unknown.

Adjourned.

December 18th, 1907.—The paper by J. T. Fetherston, Assoc. M. Am. Soc. C. E., entitled "Municipal Refuse Disposal: An Investigation," is to be presented. Because of the necessity for going to press with this number of *Proceedings* in advance of this meeting, the publication of the minutes will be deferred until January, 1908.

OF THE BOARD OF DIRECTION.

(Abstract.)

November 5th, 1907.—Past-President Noble in the chair; T. J. McMinn, acting as Secretary; and present, also, Messrs. Bissell, Bowman, Gibbs, Hazen, Knap, and Smith.

Applications were considered and other routine business transacted.

Five Associate Members were transferred to the grade of Member, and sixteen candidates for Junior were elected.

Adjourned.

December 3d, 1907.—Vice-President Bensel in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs, Bowman, Christie, Landreth, Noble, Schneider, Sherrerd, Smith, Stearns, Swensson, and Tillson.

Denver, Colorado, was selected as the place for holding the Fortieth Annual Convention of the Society, and the time for holding that Convention was fixed as June 30th to July 3d, inclusive.

The date for holding the first Society meeting in 1908 was changed from January 1st to January 8th.

Messrs. C. M. Ingersoll, Jr., James H. Brace, and Chas. Warren Hunt were appointed a Committee to take charge of the arrangements of the Annual Meeting.

The following resignations were accepted:

John A. Cosmus, H. P. Macdonald, J. A. McCrea, Edward B. Thornhill, Charles G. Waitt, S. T. Wellman.

Applications were considered and other routine business transacted.

Six Associate Members were transferred to the grade of Member, and ten candidates for Junior were elected.

Adjourned.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, January 8th, 1908.—8.30 P. M.—Ballots for membership will be canvassed, and there will be an informal discussion on The Use of Reinforced Concrete in Engineering Structures. E. P. Goodrich, M. Am. Soc. C. E., will introduce the discussion, and it is hoped that it will be continued by a number of others. All are invited to speak or to send written communications on the subject.

Wednesday and Thursday, January 15th and 16th, 1908.—The Fifty-fifth Annual Meeting will be held. The Business Meeting will be called to order at 10 o'clock on Wednesday morning at the Society House. The Annual Reports will be presented, officers for the ensuing year elected, members of the Nominating Committee appointed, a proposed amendment to the Constitution presented for action, the Report of the Special Committee on Rail Sections, printed in *Proceedings* for August, 1907, page 290, will be presented for discussion, and other business transacted.

Arrangements for the Annual Meeting have been placed in the hands of a committee composed of Messrs. C. M. Ingersoll, Jr., James H. Brace, and Charles Warren Hunt, and a general programme will soon be issued.

Wednesday, February 5th, 1908.—8.30 P. M.—Ballots for membership will be canvassed, and two papers will be presented for discussion, as follows: "Overhead Construction for High-Tension Electric Traction or Transmission," by R. D. Coombs, Assoc. M. Am. Soc. C. E.; and "A New Suspension for the Contact Wires of Electric Railways Using Sliding Bows," by Joseph Mayer, M. Am. Soc. C. E.

These papers are printed in this number of *Proceedings*.

ANNUAL CONVENTION.

The Board of Direction at its meeting, December 3d, 1907, decided that the Fortieth Annual Convention shall be held in Denver, Colo., beginning on Tuesday, June 30th, and ending Friday, July 3d, 1908.

The Secretary thinks it is wise in announcing the above fact to state that since that time it has been decided to hold the Democratic National Convention in Denver beginning July 7th, 1908, and it seems probable that a change in the date of our Convention will be necessary on that account. This will have to be decided by the Board of Direction at its next meeting, and the result will be announced later.

NOMINATING COMMITTEE.

The Constitution provides that at the Annual Meeting of each year, seven Corporate Members, not officers of the Society, one from each of the Geographical Districts into which the Society is divided for this purpose, shall be appointed by the meeting to serve for two years. In consequence of the death of Charles Davis, M. Am. Soc. C. E., it will be necessary to appoint two members for District No. 4.

The usual blank request for suggestions as to representatives of each district, for presentation to the meeting, has been mailed to Corporate Members.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Society of Engineers, 17 Victoria Street, Westminster, S. W., England.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Civil Engineers' Club of Cleveland, 718 Caxton Building, Cleveland, Ohio.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa.

Engineers' Society of Western Pennsylvania, 803 Fulton Building, Pittsburg, Pa.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

Louisiana Engineering Society, 604 Tulane-Newcomb Building, New Orleans, La.

Engineers' Club of Central Pennsylvania, Corner Second and Walnut Streets, Harrisburg, Pa.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Teknisk Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Société des Ingénieurs Civils de France, 19 Rue Blanche, Paris, France.

Svenska Teknologföreningen, Brunkebergstorg 18, Stockholm, Sweden.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Pacific Northwest Society of Engineers, 617–618 Pioneer Building, Seattle, Wash.

Institution of Naval Architects, 5 Adelphi Terrace, London. W. C., England.

Memphis Engineering Society, Memphis, Tenn.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

The Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Australasian Institute of Mining Engineers, Melbourne, Victoria. Australia.

Cleveland Institute of Engineers, Middlesbrough, England.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Rochester Engineering Society, Rochester, N. Y.

Brooklyn Engineers' Club, 197 Montague Street, Brooklyn, N. Y.

Montana Society of Engineers, Butte, Montana.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only, are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendix* to the Annual Report of the Board of Direction for the year ending December 31st, 1906, contains a summary of all searches made to that date.

*Proceedings, Vol. XXXIII, p. 20 (January, 1907).

ACCESSIONS TO THE LIBRARY.

(From November 12th to December 9th, 1907.)

DONATIONS.*

PLANE SURVEYING.

A Text-book and Pocket Manual. By John Clayton Tracy. Morocco, 7 x 4 in., illus., 27 + 794 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907. $3.00.

It is stated in the preface to this book that no attempt has been made to cover the whole field of surveying, the aim of the author being only to meet the requirements of the new methods of teaching surveying, especially in connection with summer courses, and to discuss thoroughly the fundamental principles and methods of plane surveying. The subject-matter is divided into three parts: I, Field Work; II, Office Work; and III, The Care and Adjustment of Instruments. The use of instruments, the general methods of procedure and the practical details of field work are explained and discussed in Part I. In Part II are shown various methods for checking, the systematic treatment of note-keeping, with illustrative examples of field work, and methods of compilation and plotting, together with chapters on finishing maps and on lettering. A critical study of the construction and adjustment of instruments, with a special chapter on their care, is made in Part III. Eighteen tables containing solutions of various problems in surveying are included, some of which are reprints. There is also an index of thirty pages.

MECANIQUE ELECTRICITE ET CONSTRUCTION

Appliquées aux Appareils de Levage: Les Ponts Roulants Actuels. Par Louis Rousselet. Paper, 11 x 7½ in., illus., 6 + 554 pp. Paris, H. Dunod et E. Pinat, 1908. 35 francs.

The Contents are: Part I, Generalities; Moteurs. Part II, Treuils; Freins; Vis sans Fin; Suspensions. Part III, Moufles et Palans. Part IV, Operateurs. Part V, Direction et Translation. Part VI, Projet des Mécanismes d'un Chariot de Pont Roulant. Part VII, Charpentes de Pont a Ames Pleines pour Poutres Principales. Part VIII, Les Ponts Roulants Actuels: Choix; Description d'Appareils Construits; Poids; Prix de Revient et de Vente. Appendice.

EXPLOITATION DU PETROLE:

Historique, Extraction, Procédés de Sondage, Geographie et Géologie. Recherches des Gites, Exploitation des Gisements Chimie, Théories de la Formation du Pétrole. Par L.-C. Tassart. Paper, 11 x 7½ in., illus., 14 + 726 pp. Paris, H. Dunod et E. Pinat, 1908. 35 francs.

In this, the first volume of this publication, the author discusses the petroleum industry only from the geological point of view. A description of the methods used in various countries in boring for the crude material is followed by a discussion of the geographical and geological distribution of petroleum, the chemical properties of crude petroleum and the principal substances which enter into its composition, and the various theories advanced as to its origin.

LES OSCILLATIONS DU MATERIEL DES CHEMINS DE FER ET LA VOIE.

Stabilité des Automobiles. Par Georges Marie. Paper, various sizes, illus., 5 vol. Paris, H. Dunod et E. Pinat, 1906-07. Vol. 1, 4 francs; Vol. 2, 2 francs; Vol. 3, 2 francs; Vol. 4, 4 francs; Vol. 5, 2 francs.

The first four volumes of this publication, crowned by the Academy of Science in December, 1906, are stated to represent a scientfic study of the oscillations of railway materials and track and the possible derailments resulting therefrom. In

* Unless otherwise specified, books in this list have been donated by the publisher.

the fifth volume the author shows how the theories and formulas given in the previous volumes may be applied to a study of the stability of automobiles. The Contents are: Vol. I, Les Dénivellations de la Voie et les Oscillations du Matériel de Chemins de Fer; Vol. II, Les Oscillations du Matériel des Chemins de Fer à l'Entrée en Courbe et à la Sortie; Vol. III, Les Grandes Vitesses des Chemins de Fer, les Oscillations du Matériel et la Voie; Vol. IV, Les Oscillations du Matériel Dues au Matériel Lui-Même; Vol. V, Formule Relative à une Condition de Stabilité des Automobiles et Spécialement des Autobus.

Gifts have also been received from the following:

Abel & Imray. 1 pam.
Am. Inst. of Elec. Engrs. 1 bound vol.
Am. Inst. of Min. Engrs. 1 pam.
Am. Ry. Eng. & M. of W. Assoc. 1 vol.
Am. Water Works Assoc. 1 bound vol., 1 vol.
Boston, Mass.-Board of Commrs. of the Dept. of Parks. 1 pam.
Boston, Mass.-Public Library. 1 pam.
Brit. Fire Prevention Comm. 1 bound vol.
Cape of Good Hope-Govt. Stationery Office. 1 pam.
Chicago, Ill.-Bureau of Statistics and Municipal Library. 1 pam.
Chicago & Alton R. R. Co. 1 pam.
Colo. Agri. Coll.-Agri. Exper. Station. 8 pam.
Coorg, India-Public Works Dept. 1 pam.
Cornell Univ. Library. 1 pam.
David Lupton's Sons Co. 1 bound vol.
Eastern Bengal and Assam-Secretariat Book Depôt. 1 pam.
Eng. Standards Comm. 1 pam.
Engrs.' Soc., Univ. of Minnesota. 2 pam.
Farley, G. P. 180 bound vol.
Fisk & Robinson. 1 pam.
Great Northern Ry. Co. 1 pam.
Hering, Rudolph. 1 pam.
Herschel, Clemens. 1 pam.
Illinois Univ.-Agri. Exper. Station. 8 pam.
Indiana-R. R. Comm. 1 map.
Johnson, G. A. 1 pam.
Luiggi, Luigi. 1 pam.
Manchester Assoc. of Engrs. 2 bound vol.
Mass.-Board of Health. 1 bound vol.
Master Car Builders' Assoc. 1 bound vol.
Mexican Ry. Co., Limited. 4 pam.
Mich.-State Board of Health. 1 bound vol.
Miss. River Comm. 1 pam.
Montreal, Que.-City Council. 1 bound vol.
New Jersey-Board of Health. 1 vol.
New Jersey-Geol. Survey. 2 bound vol.
New South Wales-Bureau of Statistics. 2 pam.
New York City-Dept. of Water Supply, Gas and Electricity. 1 pam.
New York-State Dept. of Health. 7 bound vol.
New York City Record. 4 bound vol.
Owen, James. 1 bound vol.
Ry. Signal Assoc. 1 pam.
Royal Military Coll. Club of Canada. 1 vol.
Royal Soc. of New South Wales. 1 vol.
St. Louis, Mo.-Public Library. 1 pam.
Smithsonian Institution. 1 bound vol., 1 vol.
South Australia-Ry. Commr. 1 pam.
South Carolina-R. R. Commrs. 1 map.
Sydney Univ. Eng. Soc. 1 vol.
Underwriters' Laboratories, Inc. 1 pam.
U. S. Bureau of Plant Industry. 1 pam.
U. S. Bureau of Statistics. 1 pam.
U. S. Bureau of the Census. 1 bound vol., 3 pam.
U. S. Bureau of Yards and Docks. 1 vol.
U. S. Corps of Engrs. 18 specif.
U. S. Interstate Commerce Comm. 14 pam.
U. S. Isthmian Canal Comm. 1 vol.
U. S. Lake Survey Office. 1 pam.
U. S. Library and Naval War Records Office. 5 pam.
Worcester, Mass.-Mayor. 15 vol.

BY PURCHASE.

Repertorium der Technischen Journal-Literatur. Herausgegeben im Kaiserlichen Patentamt, Jahrgang, 1906. Berlin, Carl Heymanns, 1907.

Resistance des Materiaux Appliquee aux Constructions, Vol. III. Par Ernest Aragon. Paris, H. Dunod et E. Pinat, 1908.

Peat: Its Use and Manufacture. By Philip R. Björling and Frederick T. Gissing. London, Charles Griffin & Company, Limited, 1907.

Kurzes Lehrbuch der Elektrotechnik. Dritte, verbesserte Auflage. Von Dr. Adolf Thomälen. Berlin, Julius Springer, 1907.

Beton-Kalender, 1908; Taschenbuch für Beton- u. Eisenbetonbau sowie die verwandten Fächer. Unter Mitwirkung hervorragender Fachmänner herausgegeben von der Zeitschrift *Beton u. Eisen*. III. Jahrgang, Pts. 1-2. Berlin, Wilhelm Ernst & Sohn, 1907.

Standard Polyphase Apparatus and Systems. By Maurice A. Oudin. Fifth Edition, Revised and Enlarged. New York, D. Van Nostrand Company; London, Sampson Low, Marston & Company, Limited, 1907.

A Handbook of Wireless Telegraphy. Its Theory and Practice, for the Use of Electrical Engineers, Students, and Operators. By James Erskine-Murray. New York, D. Van Nostrand Company; London, Crosby Lockwood and Son, 1907.

A Treatise on the Law of Municipal Ordinances. By Eugene McQuillin, of the St. Louis Bar. Chicago, Callaghan & Company, 1904.

The Sanitary Evolution of London. By Henry Jephson. Brooklyn, N. Y., A. Wessels Company, 1907.

SUMMARY OF ACCESSIONS.

From November 12th to December 9th, 1907.

Donations (including 11 duplicates)	260
By purchase	10
Total	270

MEMBERSHIP.

ADDITIONS.

(November 12th to December 10th, 1907.)

MEMBERS.

		Date of Membership.
BALCH, WILLIAM HOYT. Engr., Aberthaw Constr. Co., 8 Beacon St., Boston, Mass..	Assoc. M. M.	April 1, 1903 Dec. 3, 1907
BLOSSOM, FRANCIS. Engr. and Contr. (Sanderson & Porter), 52 William St., New York City		Dec. 4, 1907
BYERS, ALEXANDER MOSBY CLAYTON. 3a Calle Puebla 7, Colonia Condesa, City of Mexico, Mexico		Nov. 6, 1907
CLAYTON, THOMAS WILEY. 2655 W. Robey St., Chicago, Ill.		Nov. 6, 1907
FARNUM, LORING NELSON. Gen. Mgr. of Constr., J. G. White & Co., 43 Exchange Pl., New York City		Dec. 4, 1907
HERRMANN, FREDERICK CHARLES. Chf. Engr., The California Development Co., Calexico, Cal		Nov. 6, 1907
MOISSEIFF, LEON SOLOMON. Asst. Engr., Dept. of Bridges, City of New York, Park Row Bldg., New York City	Jun. Assoc. M. M.	Dec. 3, 1895 Sept. 5, 1900 Dec. 3, 1907
PITZMAN, JULIUS. Surv. and Civ. Engr., 615 Chestnut St., St. Louis, Mo		Dec. 4, 1907
ROCKWELL, JAMES VINCENT. Civ. Engr., U. S. N., Navy Yard, Mare Island, Cal	Jun. Assoc. M. M.	April 3, 1900 Feb. 4, 1903 Nov. 5, 1907
ROHRER, JACOB BOMBERGER. Asst. Mgr., American-Hawaiian Eng. & Constr. Co., Ltd., 332 Turk St., San Francisco, Cal		Nov. 6, 1907
SMITH, HOWARD EVERETT. Res. Engr., Dept. of State Engr. and Surv., 106 E. First St., Oswego, N. Y		Nov. 6, 1907
SUMNER, ROBERT SWAN. 204 Commonwealth Bldg., Denver, Colo	Assoc. M. M.	June 3, 1903 Nov. 5, 1907
TERRY, JOHN HERMON. Secy. and Treas., Latta & Terry Constr. Co., 1319 Penna. Bldg., Philadelphia, Pa		Oct. 2, 1907
VAN ALSTYNE, HENRY ARTHUR. 116 Bay 26th St., Bensonhurst, N. Y	Assoc. M. M.	June 6, 1900 Dec. 3, 1907

ASSOCIATE MEMBERS.

ALTSTAETTER, FREDERICK WILLIAM. P. O. Box 1240, Pittsburgh, Pa	Nov. 6, 1907
ATWOOD, EDWARD FRANKLIN. 29 Batavia St., Boston, Mass.	June 5, 1907
BASS, FREDERIC HERBERT. 116 Beacon St., Minneapolis, Minn.	Nov. 6, 1907
BATES, WILLIAM BERNARD. City Engr., Roanoke, Va	Nov. 6, 1907
BEATTY, PHILIP ASFORDBY. Asst. Engr., B. & O. R. R. Co., 231 E. North Ave., Baltimore, Md	Nov. 6, 1907

ASSOCIATE MEMBERS (*Continued*).

Name and Address		Date of Membership.
BEBB, EDWARD CROSBY. Engr., U. S. Reclamation Service, Glendive, Mont.		Nov. 6, 1907
BEEKMAN, JOHN VAN DERVEER, JR. Boston Mgr., Purdy & Henderson, 101 Tremont St., Boston, Mass.	Jun. Assoc. M.	Sept. 3, 1901 July 10, 1907
BENNETT, CHARLES NOBLE. Charleroi, Pa.		Dec. 4, 1907
BOUGHTON, WILL HAZEN. Head of Civ. Eng., Dept. of West Virginia Univ., and Cons. Engr. to the County Court of Monongalia County, W. Va.; Morgantown, W. Va.		Nov. 6, 1907
BRATTON, EDWARD ELISHA. 5034 Cedar Ave., Philadelphia, Pa.		Oct. 2, 1907
CAUTHORN, EDWARD BEAUFORD. City Engr., Columbia, Mo.		June 5, 1907
DIECK, ROBERT GEORGE. Mohawk Bldg., Portland, Ore.		Nov. 6, 1907
DODGE, SAMUEL DOUGLASS. Asst. Engr. with the Board of Water Supply of the City of New York, Cornwall-on-Hudson, N. Y.		Nov. 6, 1907
DONAHEY, JOSEPH ALEXANDER. Res. Engr., L. S. & M. S. R. R., Darrowville, Ohio		Dec. 4, 1907
ESPENSHADE, EDWARD BOWMAN. Res. Engr., C., M. & St. P. Ry. Co. of Mont., Roundup, Mont.		Nov. 6, 1907
FISCHER, THEODORE CHRISTIAN. 1018 E. Grand St., Elizabeth, N. J.		Dec. 4, 1907
GRISWOLD, HARRY TODD. 67 West 38th St., New York City	Jun. Assoc. M.	Oct. 6, 1903 Dec. 4, 1907
HANNA, WALTER SCOTT. Asst. Engr., Pennsylvania Dept. of Health, Harrisburg, Pa.	Jun. Assoc. M.	Oct. 6, 1903 June 5, 1907
HATTAN, WILLIAM CARY. Camp No. 2, Altapass, N. C.		Nov. 6, 1907
HOLLEY, CARL HIRAM. Gen. Supt. and Chf. Engr., Mt. Whitney Power Co., Visalico, Cal.		June 5, 1907
LEMEN, WILLIAM CASWELL SMITH. U. S. Engr. Office, Brunswick, Ga.		July 10, 1907
MACDIARMID, MILO STUART. 205 Old P. O. Bldg., Detroit, Mich.		Sept. 4, 1907
MURRAY, RAY. Res. Engr., Poughkeepsie Bridge, Poughkeepsie, N. Y.	Jun. Assoc. M.	Oct. 6, 1903 Dec. 4, 1907
OBREITER, JOSEPH WILLIAM. 908 Castle Point Terrace, Hoboken, N. J.		Nov. 6, 1907
PISTOR, GEORGE EMIL JOHN. Designing Engr., Hay Foundry & Iron Works, 114 East 28th St., New York City	Jun. Assoc. M.	Dec. 3, 1901 July 10, 1907
PORTER, SAM GRAHAM. Chf. Engr., Arkansas Val. Sugar Beet & Irrigated Land Co., Holly, Colo.		Oct. 2, 1907
QUIMBY, CHARLES HENRY, JR. Res. Engr., N. Y., W. & B. Ry., 220 So. Fulton Ave., Mt. Vernon, N. Y.		Dec. 4, 1907
RICHARDSON, JOHN FRANCIS. U. S. Reclamation Service, Grants Pass, Ore.	Jun. Assoc. M.	Oct. 3, 1899 June 5, 1907

ASSOCIATE MEMBERS (*Continued*).

		Date of Membership.
RUGG, WARREN FULLER. 147 Bay St., Peekskill, N. Y.		Nov. 6, 1907
SPIKER, WILLIAM THOMAS CLARE. 145 Westcombe Hill, Blackheath, London, England		June 5, 1907
STEARNS, RALPH HAMILTON. Asst. Engr. Designer, Board of Water Supply, 299 Broadway, New York City		Dec. 4, 1907
STUBBLEFIELD, GARFIELD. Hermiston, Ore		Nov. 6, 1907
SYKES, GEORGE. Bldg. Constr., 1123 Broadway, New York City	Jun. Assoc. M.	May 1, 1906 Dec. 4, 1907
WAGNER, HARRY EDWARD. 116 Huntington Ave. Boston, Mass		Nov. 6, 1907
WASSNER, MICHAEL. Belfast House, Belfast, N. Y.		June 5, 1907
WOODCOCK, HENRY WRIGHT. 263 Fifty-second St., Brooklyn, N. Y.	Jun. Assoc. M.	Dec. 1, 1903 Dec. 4, 1907
ZABRISKIE, ALBERT MENGER. 161 E. Front St., Plainfield, N. J.		Dec. 4, 1907

ASSOCIATES.

ANDERSON, ROBERT. 2461 Grandin Rd., Cincinnati, Ohio		Nov. 6, 1907
MCBURNEY, HENRY. Draftsman, Am. Bridge Co., Pencoyd Plant, 1409 Locust St., Philadelphia, Pa.	Jun. Assoc.	Jan. 5, 1904 Nov. 6, 1907

JUNIORS.

BARKER, JAMES MADISON. Mass. Inst. Tech., Boston, Mass.	Oct. 1, 1907
BENEDICT, NATHAN. Asst. Engr., Changuinola Ry., Bocas del Toro, Panama	Oct. 1, 1907
CANTWELL, HERBERT EDWARD. M. of W. Dept., N. Y. C. & H. R. R., Albany, N. Y.	Dec. 3, 1907
DRIGGS, EDWIN LEROY. Junior Engr., U. S. Reclamation Service, Lujane, Colo	Nov. 5, 1907
GEARHART, HEBER GASSLER. Box 26, Duquesne, Pa.	Nov. 5, 1907
HATCH, EVERETT HAMILTON. 717 First St., Napa, Cal	Nov. 5, 1907
LAMB, WILLIAM ALFRED. Sacramento, Cal	Nov. 5, 1907
LEWIS, CHESTER BROOKS. Asst. Engr., Indianapolis Water Co., 113 Monument Pl., Indianapolis, Ind	Nov. 5, 1907
MILLER, FRITZ. Care, Div. Engr., R. G. W. R. R., Salt Lake City, Utah	June 4, 1907
PACE, FULTON. Caldwell, Idaho	Nov. 5, 1907
SCHLICKEISEN, ALBERT AUGUST. Care, Buckley Eng., & Constr. Co., 624 Madison Ave., New York City	Dec. 3, 1907
STOW, MULFORD. Middletown, N. Y.	Sept. 3, 1907
SWETT, EVERETT HAROLD. 78 Woodbine St., Providence, R. I.	Oct. 1, 1907
VAN HORNE, JOHN RUSSELL. 29 Broadway, New York City.	Nov. 5, 1907
WARD, GEORGE MERRITT. Care, J. G. White & Co., Inc., Hatfield, Wis	Nov. 5, 1907

DEATHS.

Cox, Abraham Beekman. Elected Member, April 1st, 1874; died February, 1906.

Handy, Edward Adino. Elected Member, January 2d, 1889; died November 21st, 1907.

Nelles, George Thomas. Elected Member, October 3d, 1888; died November 15th, 1907.

Rumsey, B. C. Elected Fellow, May 12th, 1870; date of death not known.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(November 12th to December 9th, 1907.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Blk., Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 808 Fulton Bldg., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York, City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Electric Railway Review*, Chicago, Ill., 10c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.
(86) *Engineering-Contracting*, Chicago, Ill.
(87) *Roadmaster and Foreman*, Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.

LIST OF ARTICLES.

Bridge.

On Classification of Existing Bridges. A. J. Himes. (85) Vol. 8.
On Maintenance of Existing Metal Bridges. B. W. Guppy. (85) Vol. 8.
Report of Committee of the Amer. Ry. Eng. and M. of W. Assoc. on Wooden Bridges and Trestles.* (85) Vol. 8.
Design for the Henry Hudson Memorial Bridge; a Concrete Rib Arch of 703 Ft. Span.* (13) Nov. 21.
The Long Key Viaduct; Description of a Two-Mile Reinforced Concrete Railway Viaduct.* Wm. Mayo Venable. (14) Nov. 23.
The Manhattan Approach of the Blackwell's Island Bridge.* (14) Nov. 28.
Empiricism and Error in Arch Design. Charles W. Comstock. (13) Nov. 28.
The Phœnixville Testimony in the Quebec Bridge Inquiry. (13) Nov. 28.
Method and Cost of Molding Large Concrete Slabs for Girder Bridges.* (86) Dec. 4.
The Queens Approach to the Blackwell's Island Bridge, New York.* (14) Dec. 7.
Pont Suspendu à Poutres Raidissantes et à Articulation Médiane.* Gisclard. (43) Pt. 3.
Note sur les Travaux de Réfection du Tablier du Pont des Saints-Pères.* Pigeaud. (43) Pt. 3.
Die Neue Rheinbrücke zwischen Ruhrort und Homberg.* (51) Serial beginning Nov. 9.
Die Marienbrücke über den Wiener Donaukanal.* Karl Rosenberg. (53) Serial beginning Nov. 22.

Electrical.

Power Work as Related to Telephone Communications. Thomas Lambert. (4) Oct.
Characteristics of Circuits Employing a Mercury-Arc Rectifier.* O. S. Beyer, J. I. Liner and A. J. Loppin. (8) Oct.
The Relation between Polarization and the Corrosion of Iron Pipes by Stray Currents.* Irving Langmuir. (8) Oct.
An Analysis of the Distribution Losses in a Large Central Station System.* L. L. Elden. (42) Nov.
Balancers Versus Three-Wire Dynamos.* B. Frankenfield. (Abstract of paper read before the National Elec. Light Assoc.) (73) Nov. 8.
The Starting, Regulating and Stopping of Continuous Current Motors.* J. T. Mould. (Abstract of paper read before the Assoc. of Engrs.-in-Charge.) (73) Nov. 8.
Aluminium as a Substitute for Copper for Electrical Transmission Purposes.* John B. Sparks. (26) Serial beginning Nov. 15.

*Illustrated.

Electrical—(Continued).

A Phenomenon of Revolving-Field Generators.* F. Punga and W. Hess. (27) Nov. 16.
Direct-Current Turbo-Generators.* H. I. C. Beyer. (27) Nov. 16.
On a Standard of Mutual Inductance.* Albert Campbell. (Abstract of paper read before the Royal Soc.) (73) Nov. 22.
Hornsey New Telephone Exchange.* George Balchin. (26) Nov. 22.
Power Plant Improvements at El Paso.* (17) Nov. 23.
Leakage Coefficient of Induction Motors.* R. E. Hellmund. (27) Nov. 23.
Rubber Insulation for Conductors. Fred J. Hall. (27) Serial beginning Nov. 23.
Characteristics of the Solenoid. Charles R. Underhill. (27) Nov. 23.
Electric Power in Textile Factories.* W. B. Woodhouse. (Paper read before the Bradford Eng. Soc.) (47) Nov. 23.
The Electromobile Co.'s New Garage.* (26) Nov. 29.
The Leakage of Induction Motors.* Rud. Goldschmidt. (73) Serial beginning Nov. 29.
Transmission System and Sub-Stations of the Dunedin City Corporation, New Zealand.* (27) Nov. 30.
Representation of Armature Reaction of the Synchronous Motor as an Equivalent Reactance.* A. S. Langsdorf. (27) Nov. 30.
Wiring for Direct-Current and Alternating-Current Motors.* Louis J. Auerbacher. (27) Dec. 7.
The Market Street Station of the New Orleans Railway & Light Company.* (14) Dec. 7; (27) Dec. 7; (17) Dec. 7.

Marine.

Ship Propulsion by Internal-Combustion Engines.* A. Vennell Coster, M. Inst. Mech. Engrs. (10) Nov.
The Cunard Turbine-Driven Quadruple-Screw Atlantic Liner *Mauretania.** (11) Nov. 8.
The Production of Steel Ingots for Large Crank-Shafts.* A. Wiecke. (Paper read before the Schiffbautechnischen Gesellschaft.) (22) Serial beginning Nov. 8.
Builders' Trials of Curtis Turbine Steamer *Creole.** Chas. B. Edwards. (Abstract from *Journal* Amer. Soc. Naval Engrs. (11) Nov. 15.
New Works on the Clyde.* (Shipbuilding.) (12) Nov. 15.
H. M. Torpedo-Boat Destroyer *Mohawk.* (11) Nov. 22.
Fire Boat Protection, Considered from the Viewpoint of the Fireman and the Engineer.* Edward F. Croker. (19) Nov. 23.
The American Fleet from an English Point of View.* Archibald S. Hurd. (10) Dec.
Beitrag zur Theorie des Schiffswiderstandes. H. Lorenz. (48) Nov. 16.

Mechanical.

Cost of Steam Shovel Work.* John C. Sesser. (85) Vol. 8.
A Study of the Heat-Losses in a Gasoline Engine.* Arthur J. Wood. (Paper read before the Amer. Assoc. for the Advancement of Sci.) (8) Oct.
Acetylene Lighting and Storing. (8) Oct.
The Nature of True Boiler Efficiency.* Walter T. Ray and Henry Kreisinger. (4) Oct.
The Present Status of the Producer-Gas Power Plant in the United States.* Robert Heywood Fernald. (4) Oct.
The Ratio of Heating Surface to Grate Surface as a Factor in Power Plant Design.* Walter S. Finlay, Jr. (42) Nov.
Coke Drawing Machines and other Machinery for Use at the Ovens in the Manufacture of Coke.* Walter W. MacFarren. (58) Nov.
The Utilization of the Waste Gases of Blast Furnaces and of Coke Ovens in Metallurgical Works.* Leon Greiner. (10) Nov.
By-Product Recovery Gas Producer Plants.* H. A. Humphrey, M. Inst. M. E. (10) Nov.
Power Gas from Bituminous Coal.* Elbert A. Harvey. (10) Nov.
The Suction Gas Producer.* F. J. Rowan, Assoc. M. Inst. C. E. (10) Nov.
Large Gas and Steam Engines.* W. H. Booth, M. Am. Soc. C. E. (10) Nov.
Recent Applications of Gas Power.* J. R. Bibbins. (10) Nov.
Producer-Gas Composition and its Influence on the Performance of Suction-Producer Plants.* Godfrey M. S. Tait. (10) Nov.
The Gasoline Automobile.* Forrest R. Jones. (10) Nov.
Gas Hygiene and Ventilation. J. H. Brearley. (Paper read at the Manchester Gas Exhibition.) (66) Nov. 5.
Motor Car Exhibition at Olympia.* (12) Serial beginning Nov. 15; (11) Serial beginning Nov. 15.
Some Grinding Problems. H. Darbyshire. (11) Nov. 15.
The Ziegler System of Peat Utilisation.* (11) Nov. 15.
Filling Balloons.* W. A. Baehr. (83) Nov. 15.
Foundry Design and Equipment.* A. R. Bellamy. (47) Nov. 16.
Gas Power as a Factor in Mine Economics.* Archibald Burnett. (16) Nov. 16.
The Mechanical Equipment of the North American Cold-Storage Building, Chicago.* (14) Nov. 16.

*Illustrated.

Mechanical—(Continued).

Changes at the Croydon Gas Company's Works; Novelty between the Retort-Houses and the Gasholders.* (66) Nov. 26.

Chemical Changes Occurring during Carbonization in Horizontal, Inclined and Vertical Retorts. Harold G. Colman. (Paper read before the Manchester and District Junior Gas Assoc.) (66) Nov. 26.

The Illinois Steel Company's New Rail Mill.* (20) Nov. 28.

Friction and Lubrication.* J. T. Nicolson. (Paper read before the Manchester Assoc. of Engrs.) (12) Serial beginning Nov. 29; (47) Serial beginning Nov. 30.

The Mechanical Plant of the Boston *Herald*.* Howard S. Knowlton. (14) Nov. 30.

New Mechanical Equipment of the Enlarged *Tribune* Building, New York.* (14) Nov. 30.

Blast for Cupolas.* E. L. Rhead. (47) Nov. 30.

A Large Coal-Storage Wharf at Superior, Wisconsin.* (14) Nov. 30.

Gasoline Engines for Automobiles; a Comparison of the Four-Cylinder and Six-Cylinder Vertical Types.* David Fergusson. (10) Dec.

Mechanical Stoking on Locomotives and Marine Boilers.* C. S. Vesey-Brown, M. Inst. C. E. (10) Dec.

Pulverized Coal and its Industrial Applications.* William D. Ennis. (9) Serial beginning Dec.

Smoke Prevention in Cities. (Abstract of report to the Chamber of Commerce, Syracuse.) (20) Dec. 5.

Some Engineering Features of the Parsons Shops of the Missouri, Kansas & Texas Ry.* (14) Dec. 7.

A Modern Boiler Shop Essential.* (Oxy-acetylene apparatus.) Harry-Ruck-Keene. (Abstract of paper read before the Inst. of Marine Engrs.) (18) Dec. 7.

Développement des Turbines à Vapeur d'Echappement.* M.-A. Rateau. (Paper read before the Soc. Belge des Ingénieurs et des Industriels.) (37) Oct.

Turbine à Vapeur de 700 Chevaux.* (34) Nov.

Moulage Mécanique des Baignoires en Fonte par le Système P. Dupont. H. Mamy. (33) Nov. 2.

La Distribution du Gaz d'Eclairage dans la Banlieue de Paris.* F. Claudet. (33) Nov. 9.

Etat Actuel de l'Industrie de l'Aluminium.* Robert Pitaval. (33) Serial beginning Nov. 16.

Installations pour l'Epuration des Gaz de Hauts Fourneaux, Système Zschocke.* Wolf. (33) Nov. 16.

Les Stations Centrales de Distribution de Froid.* J. de Loverdo. (33) Nov. 23.

Stau- und Regelvorrichtungen bei Dampffördermaschinen.* Grunewald. (48) Serial beginning Nov. 2.

Untersuchung einer Mittelbaren Dampfmaschinen-regelung.* W. Gensecke. (48) Serial beginning Nov. 16.

Die Aufschliesung der Nickelerzlagerstätten in Neukaledonien.* G. Dieterich. (48) Serial beginning Nov. 16.

Metallurgical.

The Electrolytic Treatment of Galena. Edward F. Kern and Herbert S. Auerbach. (6) Nov.

Vanadium Steel.* J. Kent Smith. (25) Dec.

Lead Smelting in Utah; a Description of the Methods in Use at Bingham Junction and at Murray.* Robert B. Brinsmade. (45) Dec.

Zur Metallographie des Roheisens. E. Heyn and O. Bauer. (50) Serial beginning Oct. 30.

Der Elektrische Induktionsofen nach dem System Röchling-Rodenhauser. H. Wedding. (50) Nov. 6.

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OVERHEAD CONSTRUCTION FOR HIGH-TENSION ELECTRIC TRACTION OR TRANSMISSION.

By R. D. Coombs, Assoc. M. Am. Soc. C. E.

To be Presented February 5th, 1908.

A proper regard for the safety of the public, and the great necessity, from an operating standpoint, of uninterrupted service on power-transmission lines and the railroad or other lines they cross, demand the most reliable type of construction.

"Crossing spans," being relatively few in number and relatively great in importance, should be built in the best manner possible, and without the same consideration of cost as that which is proper for a line on private right of way.

The choice of a type of construction for transmission companies, on private right of way, may be said to depend on the cost of construction *versus* the cost of interruptions to service, and maintenance. This is also true, though to a less extent, of certain classes of railroad power lines.

Where transmission-company power lines cross railroads, or when high-tension wires are used by railroads for purposes of electric traction, the cost of failures of construction will be found to exceed the additional cost of good construction.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

Interruptions of service on transmission lines, and accidental contact with other lines, can usually be charged to the following causes:

1st.—Short-circuiting by birds, branches, kites or other objects spanning the wires;

2d.—Burning cross-arms or pins by discharges from the power line;

3d.—Fires burning wooden poles;

4th.—Failures due to lightning;

5th.—Electrical failure of insulators;

6th.—Careless or malicious breaking of insulators;

7th.—Failures due to wind and ice storms, or to floods.

Short-circuiting, while not eliminated, will be reduced as much as appears to be practicable by spacing the wires not less than 30 in. apart and cutting back standing timber from the immediate vicinity of the line.

The burning of pins or poles will be prevented by the use of steel superstructures and metallic pins.

Steel superstructures will not be in danger from lightning, and the addition of a ground wire above the power wires should lessen the likelihood of other lightning troubles on the line.

The electrical failure of insulators is mainly a question of cost.

Malicious injury cannot be guarded against, but may be lessened by a campaign of education.

Mechanical failures, due to storms, may be guarded against in the design; and a properly designed structure may be considered as secure as other forms of steel construction.

Ice Load.—Depending on the climate, allowance must be made for accumulations of sleet upon all wires and superstructures. The latest practice regarding sleet loads varies from no load to a thickness of 1 in. Experience with telephone and telegraph lines indicates that sleet formation ranges from a thin film to a hollow cylinder 2½ in. in diameter and ½ in. thick. It is probable, however, that these large formations are not continuous, or do not remain in place during high winds.

The weight of sleet, particularly the larger formations—which may be partly snow—should be assumed as somewhat less than that of clear ice. It will be noted that a thickness of ½ in. of ice is hereafter

assumed to remain in place during a high wind, the weight being assumed as 0.033 lb. per cu. in.

Wind Loads.—No exact specification for wind pressure has, as yet, been very generally accepted. Perhaps the most common method has been to adopt pressures of from 30 to 50 lb. per sq. ft., as required by bridge specifications, and modify them for cylindrical surfaces. In reality, these wind pressures, as used in bridge practice, include an allowance for vibration, and are not considered as likely to act over extended surfaces.

Since the publication of Sir Isaac Newton's law for the pressures exerted by moving fluids—which, for wind pressures, may be reduced to the form:

$$P = \frac{K}{370} V^2$$

in which P = pressure, in pounds per square foot,
and V = velocity, in miles per hour—

many investigators have experimented, with a view to the determination of values for the constant, K. For normal pressures against thin flat surfaces,* most of the results indicate values between:

$$P = 0.0035\ V^2 \quad \text{.......................(1)}$$

and

$$P = 0.0049\ V^2 \quad \text{.......................(2)}$$

These formulas, modified to apply to cylindrical surfaces, become

$$P = 0.0021\ V^2 \quad \text{.......................(3)}$$

and

$$P = 0.0029\ V^2 \quad \text{.......................(4)}$$

The Berlin-Zossen high-speed tests, in which wind pressures against trains were measured, gave the formula:

$$P = 0.0027\ V^2$$

and, using a rounded "nose" on the forward end:

$$P = 0.0025\ V^2$$

In 1903-04, at Niagara Falls, Mr. H. W. Buck† conducted a series of tests on a stranded cable having a span of 950 ft. Dynamometers attached to the center of the cable gave direct readings of the wind pressures occurring in conjunction with velocities indicated by a Government standard anemometer, also placed at the center of the span.

The following limiting conditions are to be noted:

The maximum velocity observed was 40 miles per hour (indicated).

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* See Report of the Special Army Engineer Board, U. S. War Department, Sept. 30, 1894.

† "The Use of Aluminum as an Electrical Conductor," by H. W. Buck, International Electrical Congress, 1904.

The single anemometer used registered velocities at the center of the span, and gave no indication of the velocities at other points.

It is probable that the stranded cable gave slightly higher results than would be the case with a solid wire.

These tests give the following formula:

$$P = 0.0025 \; V^2 \dots\dots\dots\dots\dots\dots (5)$$

Omitting from consideration the effects of tornadoes and cyclones, it is necessary to determine, or assume, the maximum velocity of the wind, for general practice or for any particular locality. Many of the results of anemometer tests may be regarded with suspicion, owing to imperfect apparatus, it being very probable that some previously recorded pressures should be reduced from 10 to 25%, to be comparable with those obtained by modern instruments.

Table 1 (U. S. Weather Bureau) shows the equivalent "actual" velocities corresponding to those "indicated" by anemometer readings.

TABLE 1.

Indicated Velocity, in miles per hour.	Actual Velocity, in miles per hour.	Indicated Velocity, in miles per hour.	Actual Velocity, in miles per hour.
0	0.	60	48.0
10	9.6	70	55.2
20	17.8	80	62.2
30	25.7	90	69.2
40	33.3	*100	*76.2
50	40.8		

The records of the United States Weather Bureau—omitting tornadoes, cyclones, and violent gales occurring in some particularly exposed situations—give a maximum indicated velocity of 100 miles per hour. The records at Bidston Observatory (Liverpool, England), from 1884 to 1888, give, as a maximum of ten severe storms, an actual velocity of 78 miles per hour.

Table 2 shows the maximum velocities observed at a number of stations by the United States Weather Bureau:

* Added by comparison.

TABLE 2.

Observatory.	Period.	Maximum Velocity Indicated.	Observatory	Period.	Maximum Velocity Indicated.
Chicago, Ill.	1871–1906	90	Savannah, Ga.	1894–1908	76
Buffalo. N. Y.	1871–1907	90	Philadelphia, Pa.	1872–1907	75
Galveston, Tex.	1894–1908	84	Bismarck, N. Dak.	1894–1908	72
New York, N. Y.	1871–1907	80	Boston, Mass.	1873–1907	72
Eastport, Me.	1873–1907	78	Salt Lake City, Utah.	1894–1908	60

Table 3 shows the three highest indicated velocities recorded by the United States Weather Bureau at the New York City station, in each year, from 1884 to 1906. The station was moved in March, 1895, from the Manhattan Life Building to the present location at 100 Broadway; the latter is evidently a more exposed position, as shown by the abrupt rise in velocities after 1895. The maximum velocity of 80 miles per hour occurred during a sleet storm.

TABLE 3.

Year.	Date.	Maximum Velocity.	Date.	Maximum Velocity.	Date.	Maximum Velocity.
1884	Oct. 18	44	Feb. 20	40	Dec. 9	40
5	Jan. 17	50	Dec. 7	50	Mar. 10	48
6	Feb. 26	64	Mar. 2	54	Jan. 9	44
7	Dec. 29	50	Nov 16	48	Feb. 12	46
8	Jan. 26	60	Mar. 5	52	Mar. 18	50
9	Jan. 17	50	Feb. 1	48	Dec. 26	48
1890	Jan. 22	55	Dec. 17	48	Feb. 5	45
1	Dec. 30	53	Mar. 14	45	Jan. 11	44
2	Jan. 26	49	Mar. 11	40	Jan. 5	40
3	Aug. 29	54	Jan. 1	48	Oct. 13	48
4	Apr. 11	48	Oct. 10	48	Jan. 12	48
5	Dec. 27	73	Mar. 28	64	Aug. 4	62
6	Mar. 4	72	Feb. 7	65	Sep. 30	56
7	Jan. 18	60	Feb. 6	60	Oct. 17	60
8	Dec. 4	78	Sep. 7	72	Nov. 11	65
9	Mar. 20	80	Jan. 25	66	Feb. 27	64
1900	Oct. 16	76	Nov. 21	76	Jan. 26	76
1	Nov. 26	72	Jan. 19	72	Feb. 5	70
2	Mar. 19	74	Jan. 1	74	Feb. 2	74
3	July 2	72	Feb. 5	72	Sep. 17	65
4	Apr. 16	73	Sep. 15	68	Mar. 8	65
5	Dec. 10	64	Feb. 7	61	Apr. 10	56
6	Mar. 10	64	Jan. 6	61	Feb. 28	59

Table 4 is a record, by months, of the number of different 12-hour periods during which a maximum velocity of 60 miles, or more, was observed at the New York City station, from 1895 to 1906, inclusive. Inasmuch as a maximum occurring late in one period and another early in the following period are both entered, a few of the entries represent the effects of the same storm.

Tables 3 and 4 indicate that, for the vicinity of New York City:

The maximum velocities occur during the winter months, when sleet may be on the wires.

Indicated velocities of more than 80 miles per hour will rarely, if ever, occur during the life of a given structure.

Indicated velocities of from 65 to 75 miles per hour may be expected several times each year, though much less frequently in conjunction with sleet.

TABLE 4.

Month.	Indicated Velocities, in miles per hour:																Totals.
	60	61	62	63	64	65	66	67	68	70	72	73	74	76	78	80	
Jan.	3	3	....	2	2	1	4	....	....	....	1	....	1	1	....	....	18
Feb.	7	2	2	1	6	2	2	2	2	3	1	....	1	....	....	....	31
Mar.	3	....	1	2	2	1	1	....	1	1	3	....	1	....	....	1	17
Apr.	....	1	....	1	....	...	....	....	....	....	....	1	....	....	....	....	3
May	1	...	1	....	1	....	....	....	....	....	....	....	....	....	....	....	3
June	1	....	....	....	....	....	1	....	....	....	1	....	....	....	....	....	3
July	....	....	....	....	....	2	1	....	....	....	1	....	....	....	....	....	4
Aug	....	....	1	....	1	....	....	....	....	....	....	....	....	1	....	....	3
Sept.	....	....	....	1	1	2	....	....	1	...	1	....	....	....	....	....	6
Oct.	1	1	....	....	....	....	....	....	....	....	....	....	....	1	....	....	3
Nov.	4	....	2	....	2	1	....	....	....	....	1	1	1	1	....	....	13
Dec.	6	1	1	2	3	1	....	....	1	....	1	1	....	....	1	....	13
Totals.	26	8	8	9	18	10	9	2	5	4	10	3	4	4	1	1	122

Assuming an indicated velocity of 100 miles per hour, or an actual velocity of 76.2 miles per hour, Equations 3 and 4 become:

$P = 12.19$ lb. per sq. ft. of projected area................(6)

and $P = 16.84$ lb. per sq. ft. of projected area................(7)

while Equation 5 becomes:

$P = 14.51$ lb. per sq. ft. of projected area................(8)

Equation 8 is a mean of Equations 6 and 7.

On long spans, the maximum pressure at one point may be considerably in excess of the equivalent uniform pressure along the wire, while very short spans may be exposed to the maximum pressure throughout their length. In the absence of a formula in which the length of span enters as a factor, Equation 5 may be regarded as approximately correct.

In view of the rare, if not improbable, occurrence of velocities greater than 90 miles per hour, "indicated," and the further improbability of such winds accompanying sleet storms, or of the sleet remaining in place, Equations 9 and 10 seem to be reasonable for general use.

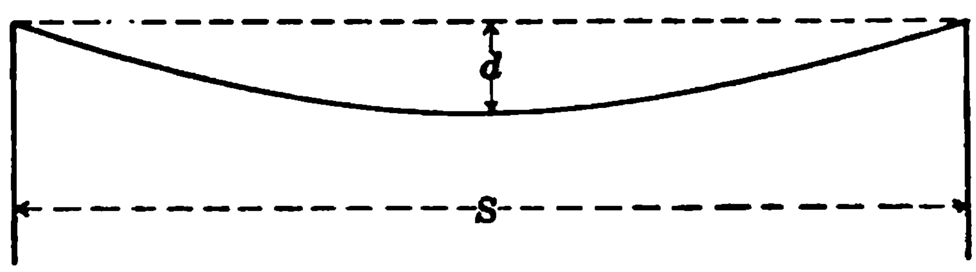
P = 12 lb. per sq. ft. of projected area of bare wires.......... (9)

P = 8 lb. per sq. ft. of projected area + ½ in. thickness of ice..(10)

Catenary Stresses.

The following mathematical treatment is not new, but the writer has found the arrangement convenient:

Ends of Span at Same Elevation.



S = span, in feet,
d = sag, in feet,
W = load per linear foot in plane of wire,
A = area of wire, in square inches.
E = modulus of elasticity,
θ = coefficient of expansion,
t = change of temperature, in degrees,
e = elongation or change of length, within elastic limit.
L_0 = length, in feet, of imaginary wire ($W = o$) at normal temperature.
L_{oc} = length, in feet of imaginary wire, cold (80° fahr. below normal temperature).
L_{oh} = length, in feet, of imaginary wire, hot (70° fahr. above normal temperature).

Index to subscripts.—

No subscript = normal conditions,
$_c$ = cold: 80° fahr. below normal + dead load,
$_i$ = cold: ice load + dead load,
$_{cw}$ = cold: wind load + dead load,
$_{iw}$ = cold: ice + wind + dead load,
$_h$ = hot: 70° fahr. above normal + dead load.

W_{iw} is the resultant of the vertical dead + ice loads and the horizontal wind load.

W_{cw} is the resultant of the vertical dead load and the horizontal wind load.

Stresses.—Substitute normal values in Equations 1, 2, 3, and 4. Assume values of T_h, T_{iw}, T_c, T_i, or T_{cw}, such that Equations 5 and 6

will give identical values of d_h, d_{tw}, etc. The tension that will give the same sag by Equations 5 and 6 (independently) is the tension resulting from that sag and the given loading.

$$T = \frac{W S^2}{8 d} \qquad (1)$$

$$L = S \left[1 + \frac{8 d^2}{3 S^2}\right] \qquad (2)$$

$$e = \frac{T L}{E A} \qquad (3)$$

$$L_o = L - e \qquad (4)$$

(70° fahr. above normal, with dead load.)

$$L_{oh} = L_o (1 + \theta t_h) \qquad e_h = \frac{L_{oh} \times T_h}{E A} \qquad L_h = L_{oh} + e_h$$

$$d_h = 0.612 \sqrt{S (L_h - S)} \qquad (5)$$

$$d_h = \frac{W_h \times S^2}{8 T_h} \qquad (6)$$

(80° fahr. below normal, with dead + ice + wind loads.)

$$L_{oc} = L_o (1 - \theta t_c) \qquad e_{tw} = \frac{L_{oc} \times T_{tw}}{E A} \qquad L_{tw} = L_{oc} + e_{tw}$$

$$d_{tw} = 0.612 \sqrt{S (L_{tw} - S)} \qquad (5)$$

$$d_{tw} = \frac{W_{tw} \times S^2}{8 T_{tw}} \qquad (6)$$

(80° fahr. below normal, with dead load.)

$$L_{oc} = L_o (1 - \theta t_c) \qquad e_c = \frac{L_{oc} \times T_c}{E A} \qquad L_c = L_{oc} + e_c$$

$$d_c = 0.612 \sqrt{S (L_c - S)} \qquad (5)$$

$$d_c = \frac{W_c \times S^2}{8 T_c} \qquad (6)$$

(80° fahr. below normal, with dead + ice loads.)

$$L_{oc} = L_o (1 - \theta t_c) \qquad e_i = \frac{L_{oc} \times T_i}{E A} \qquad L_i = L_{oc} + e_i$$

$$d_i = 0.612 \sqrt{S (L_i - S)} \qquad (5)$$

$$d_i = \frac{W_i \times S^2}{8 T_i} \qquad (6)$$

(80° fahr. below normal, with dead + wind loads.)

$$L_{oc} = L_o (1 - \theta t_c) \qquad e_{cw} = \frac{L_{oc} \times T_{cw}}{E A} \qquad L_{cw} = L_{oc} + e_{cw}$$

$$d_{cw} = 0.612 \sqrt{S (L_{cw} - S)} \qquad (5)$$

$$d_{cw} = \frac{W_{cw} \times S^2}{8 T_{cw}} \qquad (6)$$

TABLE 5.—STRANDED WIRE—STEEL (Galvanized).

Diameter.	No. and Gauge of Wires.	Area, in square inches.	ULTIMATE STRENGTH.		
			Siemens-Martin, 75 000 lb.	High-tension, 125 000 lb.	Extra high tension, 187 000 lb.
5/8 in.	7— 5	0.2356	19 000	25 000	42 000
9/16 "	7— 6½	0.1922	14 500	21 100	34 500
1/2 "	7— 8	0.1443	11 000	18 000	27 000
7/16 "	7— 9	0.1204	9 000	15 000	22 500
3/8 "	7—11	0.0882	6 800	10 500	17 250
5/16 "	7—12	0.0606	4 860	8 100	12 100
9/32 "	7—12¾	0.0496	4 380	7 300	10 900
1/4 "	7—13¼	0.0379	3 050	5 100	7 600
7/32 "	7—15	0.0293	2 500	4 100	6 100
3/16 "	7—16	0.0218	2 000	3 300	4 900
5/32 "	7—17½	0.0149	1 350	2 230	3 300
1/8 "	7—19	0.0097	900	1 500	2 250

Diameter.	LOAD PER LINEAR FOOT (VERTICAL).		PRESSURE PER LINEAR FOOT (HORIZONTAL).		LOAD PER LINEAR FOOT (PLANE OF RESULTANT).	
	Dead.	Dead + ½ in. of ice	At 8 lb. per sq. ft.	At 15 lb. per sq. ft.	Wind, at 8 lb.	Wind, at 15 lb.
			½ in. of ice.	½ in. of ice.	½ in. of ice.	½ in. of ice.
7/8 in.	.....	.....	1.250	2.344	.....	.....
13/16 "	.....	.....	1.208	2.266	.....	.....
3/4 "	.....	.....	1.167	2.188	.....	.....
11/16 "	.....	.....	1.125	2.109	.....	.....
5/8 "	.....	.....	1.083	2.031	.....	.....
9/16 "	.....	.....	1.042	1.953	.....	.....
1/2 "	0.510	1.182	1.000	1.875	1.510	2.190
7/16 "	0.415	0.998	0.958	1.797	1.383	2.055
3/8 "	0.295	0.889	0.917	1.719	1.248	1.918
5/16 "	0.210	0.715	0.875	1.641	1.130	1.790
9/32 "	0.144	.....	0.854	1.602	.....	.....
1/4 "	0.125	0.592	0.833	1.563	1.022	1.671
7/32 "	0.095	0.542	0.812	1.523	0.976	1.617
3/16 "	0.075	0.508	0.792	1.484	0.938	1.567
5/32 "	0.055	0.463	0.771	1.445	0.899	1.517
1/8 "	0.032	0.421	0.750	1.406	0.860	1.468

TABLE 6.—SOLID WIRE—COPPER (Hard-Drawn).

Gauge, B. & S.	Diameter, in inches.	Area, in square inches.	Area, in circular mils.	Ultimate strength, in pounds.	Factor of safety = 2½.
0 000	0.4600	0.1662	211 600	8 310	3 325
000	0.4096	0.1318	167 800	6 590	2 635
00	0.3648	0.1045	133 080	5 220	2 090
0	0.3249	0.0829	105 530	4 560	1 825
1	0.2893	0.0657	83 690	3 740	1 495
2	0.2576	0.0521	66 370	3 120	1 250
3	0.2294	0.0413	52 630	2 480	990
4	0.2043	0.0328	41 740	1 960	785
5	0.1819	0.0260	33 100	1 560	625
6	0.1620	0.0206	26 250	1 240	495
7	0.1443	0.0163	20 820	980	390
8	0.1285	0.0130	16 510	780	310
9	0.1144	0.0103	13 090	620	250
10	0.1019	0.0082	10 380	490	195
11	0.0907	0.0065	8 230	390	155
12	0.0808	0.0051	6 530	305	120
13	0.0720	0.0041	5 180	245	100
14	0.0641	0.0031	4 110	185	75

Gauge, B. & S.	LOAD PER LINEAR FOOT (VERTICAL).		PRESSURE PER LINEAR FOOT (HORIZONTAL).		LOAD PER LINEAR FOOT (PLANE OF RESULTANT).	
	Dead.	Dead + ½ in. of ice.	At 8 lb. per sq. ft. ½ in. of ice.	At 15 lb. per sq. ft. ½ in. of ice.	Wind, at 8 lb. ½ in. of ice.	Wind, at 15 lb. ½ in. of ice.
0 000	0.641	1.238	0.973	1.824	1.575	2.205
000	0.509	1.074	0.940	1.762	1.427	2.064
00	0.403	0.940	0.910	1.706	1.309	1.948
0	0.320	0.833	0.883	1.656	1.214	1.854
1	0.253	0.744	0.860	1.612	1.137	1.775
2	0.202	0.673	0.838	1.572	1.075	1.710
3	0.159	0.613	0.820	1.537	1.024	1.655
4	0.126	0.564	0.803	1.505	0.981	1.607
5	0.100	0.524	0.788	1.477	0.946	1.567
6	0.079	0.491	0.775	1.453	0.917	1.534
7	0.063	0.464	0.763	1.430	0.893	1.503
8	0.050	0.441	0.752	1.411	0.872	1.479
9	0.039	0.421	0.743	1.393	0.854	1.456
10	0.032	0.406	0.735	1.377	0.840	1.436
11	0.025	0.392	0.727	1.363	0.826	1.418
12	0.020	0.381	0.721	1.351	0.815	1.404
13	0.016	0.372	0.715	1.340	0.806	1.391
14	0.012	0.363	0.709	1.330	0.796	1.379

Ultimate strength = 50 000 to 60 000 lb. per sq. in
Modulus of elasticity = E = 16 000 000
Coefficient of expansion = θ = 0.0000096

TABLE 7.—STRANDED WIRE—COPPER (Hard-Drawn).

Gauge, B. & S.	Diameter, in inches.	Area, in square inches.	Area, in circular mils.	Ultimate strength, in pounds.	Factor of safety = 2½.
	0.999	0.5892	750 000	.....	.....
	0.963	0.5495	700 000	.....	.....
	0.927	0.5102	650 000	.....	.....
	0.891	0.4715	600 000	.....	.....
	0.855	0.4318	550 000	.....	.....
	0.819	0.3924	500 000	.....	.....
	0.770	0.3523	450 000	.....	.....
	0.728	0.3141	400 000	.....	.....
	0.679	0.2750	350 000	.....	.....
	0.630	0.2360	300 000	.....	.....
	0.590	0.1965	250 000	.....	.....
0 000	0.530	0.1662	211 600	9 970	3 990
000	0.470	0.1318	167 800	7 910	3 160
00	0.420	0.1045	133 080	6 270	2 510
0	0.375	0.0829	105 530	4 970	1 990
1	0.330	0.0657	83 690	3 940	1 580
2	0.291	0.0521	66 370	3 130	1 250
3	0.261	0.0413	52 630	2 480	990
4	0.231	0.0328	41 740	1 970	790

Circular mils, or B. & S. gauge.	Load per Linear Foot (Vertical).		Pressure per Linear Foot (Horizontal).		Load per Linear Foot (Plane of Resultant).	
	Dead.	Dead + ½ in. of ice.	At 8 lb. per sq ft ½ in. of ice.	At 15 lb. per sq. ft. ½ in. of ice.	Wind, at 8 lb. ½ in. of ice.	Wind. at 15 lb. ½ in. of ice.
750 000	2.288	3.220	1.333	2.499	.....	.....
700 000	2.135	3.045	1.309	2.454	.....	.....
650 000	1.983	2.871	1.285	2.409	.....	.....
600 000	1.830	2.696	1.261	2.364	.....	.....
550 000	1.678	2.521	1.237	2.319	.....	.....
500 000	1.525	2.345	1.213	2.274	.....	.....
450 000	1.373	2.163	1.180	2.213	.....	.....
400 000	1.220	1.984	1.152	2.160	.....	.....
350 000	1.068	1.801	1.119	2.099	.....	.....
300 000	0.915	1.618	1.067	2.038	.....	.....
250 000	0.762	1.440	1.060	1.988	.....	.....
0 000	0.645	1.286	1.020	1.913	1.641	2.305
000	0.513	1.116	0.980	1.838	1.485	2.150
00	0.406	0.978	0.947	1.775	1.361	2.036
0	0.322	0.866	0.917	1.719	1.261	1.925
1	0.255	0.771	0.887	1.663	1.175	1.833
2	0.203	0.695	0.861	1.614	1.107	1.757
3	0.160	0.633	0.841	1.576	1.053	1.698
4	0.127	0.582	0.821	1.539	1.006	1.645

Ultimate strength = 60 000 lb. per sq. in.

TABLE 8.—Stranded Wire—Aluminum.

Gauge, B. & S.	Diameter, in inches.	Area, in square inches.	Area, in circular mils.	Ultimate strength, in pounds.	Elastic limit.	Factor of safety = 2½.		
	1.085	......	800 000	......	60%	......	23 000 lb. per sq. in.	37 wires.
	0.996	0.5892	750 000	13 550	......	5 420		
	0.963	0.5495	700 000	12 640	......	5 050		
	0.928	0.5102	650 000	11 730	......	4 690		
	0.891	0.4715	600 000	10 840	......	4 340		
	0.854	0.4318	550 000	9 930	......	3 970		
	0.814	0.3924	500 000	9 025	......	3 610		
	0.772	0.3528	450 000	8 160	......	3 240	" "	19 wires.
	0.725	0.3141	400 000	7 225	......	2 890		
	0.679	0.2750	350 000	6 325	......	2 530		
	0.621	0.2360	300 000	5 430	......	2 170		
	0.567	0.1965	250 000	4 520	......	1 810	" "	7 wires.
0 000	0.522	0.1662	......	3 820	......	1 530		
000	0.464	0.1318	......	3 160	65%	1 265	24 000 lb. per sq. in.	
00	0.414	0.1045	......	2 510	......	1 000		
0	0.368	0.0829	......	1 990	......	795		
1	0.328	0.0657	......	1 575	......	630		
2	0.291	0.0521	......	1 250	......	500		
3	0.261	0.0413	......	990	......	395		
4	0.231	0.0328	......	790	......	315		

Circular mils, or B. & S. gauge.	Load per Linear Foot (Vertical).		Pressure per Linear Foot (Horizontal).		Load per Linear Foot (Plane of Resultant).	
	Dead.	Dead + ½ in. of ice.	At 8 lb. per sq. ft.	At 15 lb. per sq. ft.	Wind, at 8 lb.	Wind, at 15 lb.
			½ in. of ice.	½ in. of ice.	½ in. of ice.	½ in. of ice.
800 000	0.736	1.691	1.357	2.544	......	......
750 000	0.690	1.620	1.331	2.495	......	......
700 000	0.644	1.554	1.309	2.454	......	......
650 000	0.598	1.486	1.285	2.410	......	......
600 000	0.552	1.417	1.261	2.364	......	......
550 000	0.506	1.348	1.236	2.318	......	......
500 000	0.460	1.278	1.209	2.268	......	......
450 000	0.414	1.205	1.181	2.215	......	......
400 000	0.368	1.130	1.150	2.156	......	......
350 000	0.322	1.055	1.119	2.099	......	......
300 000	0.276	0.973	1.081	2.026	......	......
250 000	0.230	0.894	1.045	1.959	......	......
0 000	0.195	0.831	1.015	1.903	1.312	2.075
000	0.155	0.755	0.976	1.830	1.234	1.979
00	0.122	0.691	0.943	1.768	1.168	1.893
0	0.097	0.637	0.912	1.710	1.112	1.825
1	0.077	0.592	0.885	1.660	1.065	1.762
2	0.061	0.553	0.861	1.614	1.023	1.706
3	0.049	0.522	0.841	1.576	0.990	1.660
4	0.039	0.491	0.821	1.539	0.958	1.616

Ultimate strength = 23 000 to 24 000 lb. per sq. in.
Modulus of elasticity = E = 9 000 000.
Coefficient of expansion = θ = 0.0000128.

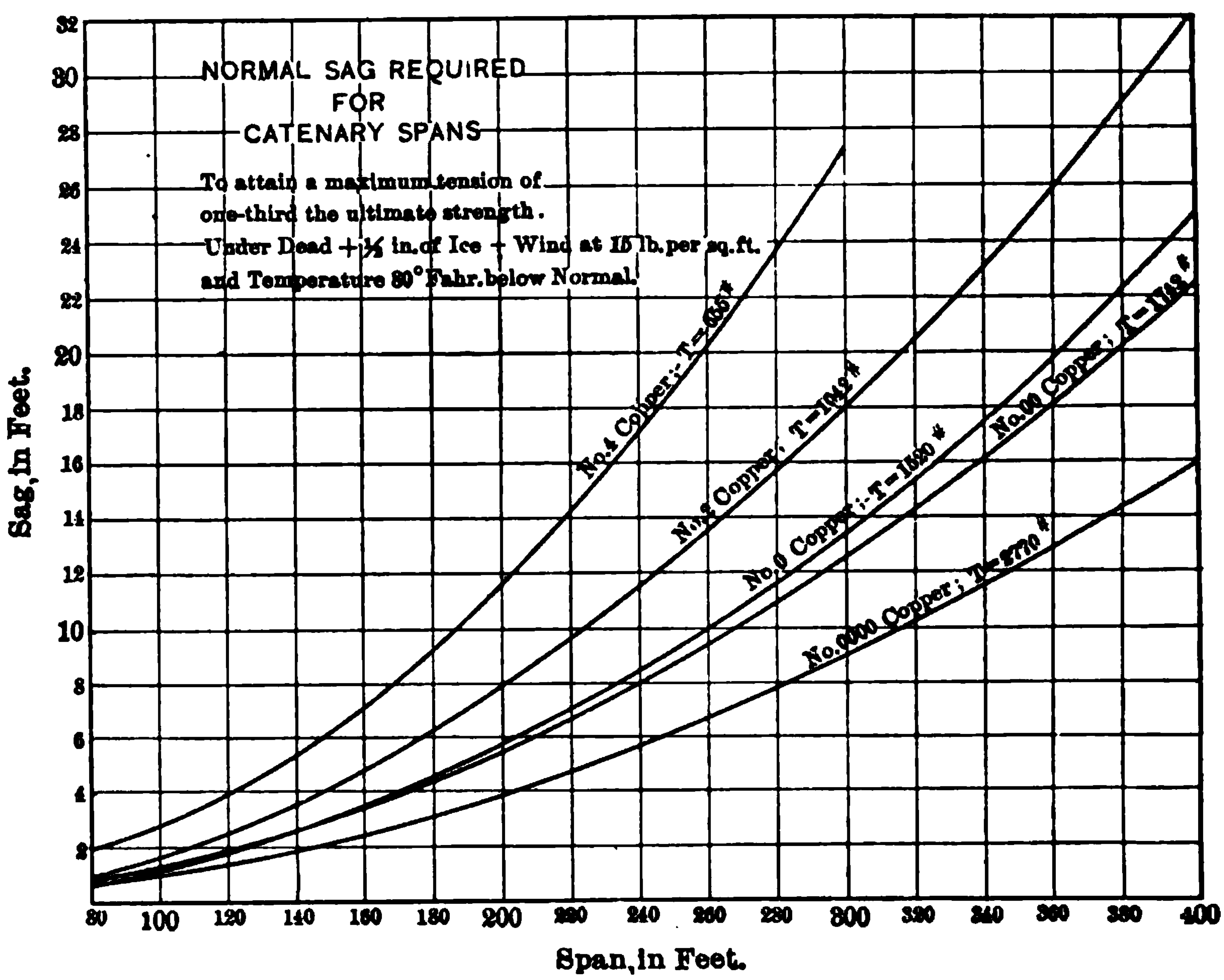
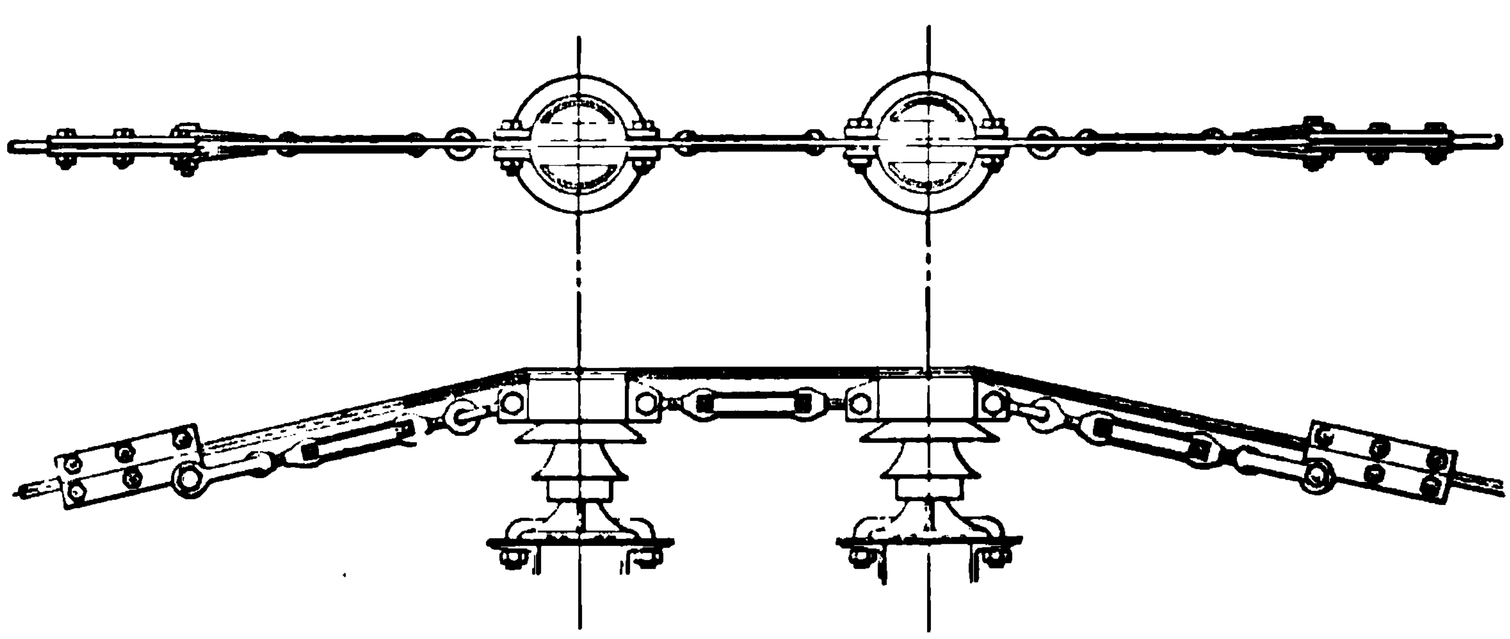


FIG. 1.

ANCHOR INSULATOR



Note:

Cap to be lined up properly and cemented to Insulator.
Neither the Cap nor Cap-cement to rest on Petticoat.
All parts to be galvanized, except inside of Cable-clamps.
Soft Copper Bushing around the wire in the Clamp.
Soft Copper Shield around the wire over the Insulator.
Serving wire No.12 B.and S.Copper.
All edges and corners to be rounded, particularly at ends of Clamp and Cap grooves

FIG. 2.

Fig. 1 shows a set of curves giving the approximate normal sags required for hard-drawn, solid, copper wire, when the maximum tension is limited to one-third the ultimate strength.

Figs. 2 and 3 show two types of anchor insulators, in which two or more insulators withstand the tension of the span, and in which an auxiliary attachment is provided in case of failure at the insulator.

ANCHOR INSULATOR

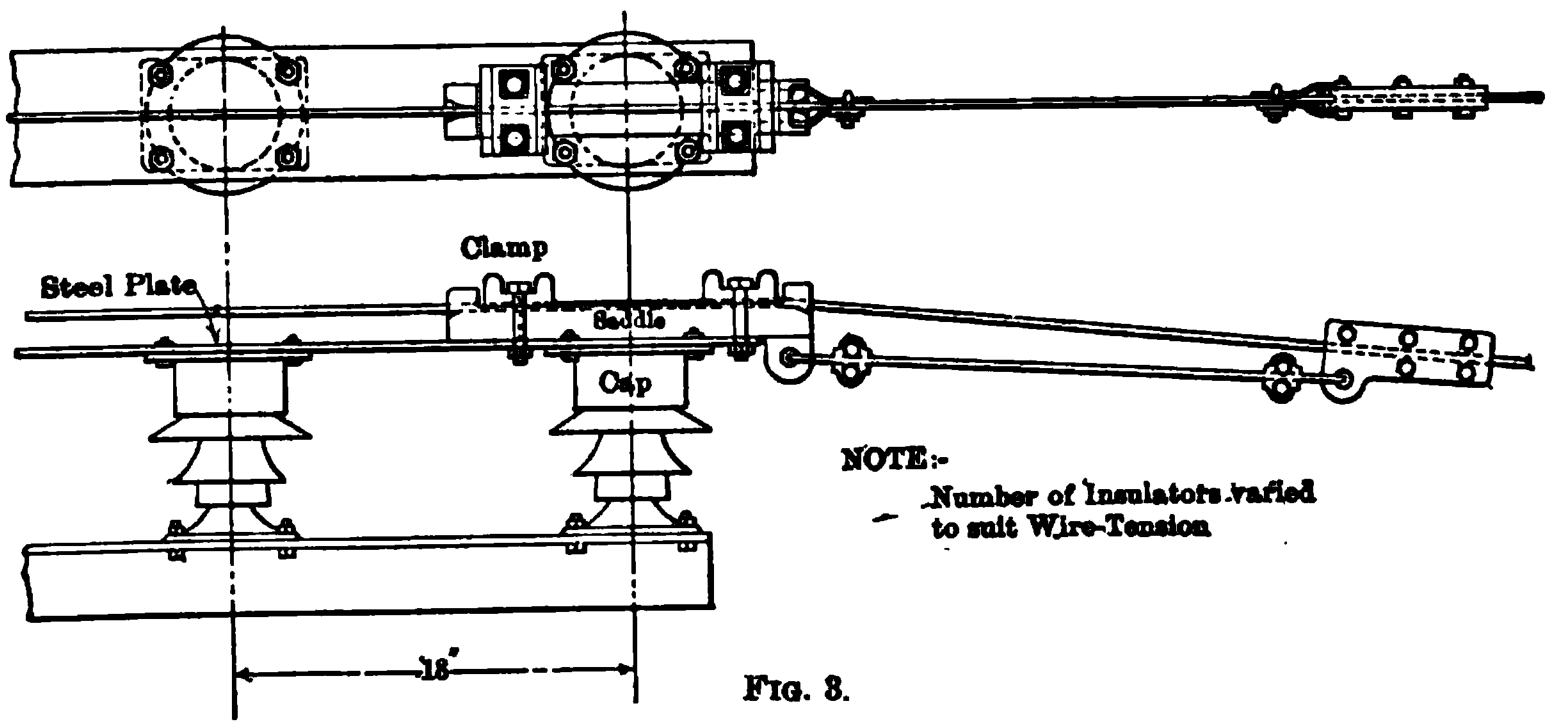


FIG. 3.

SPECIFICATIONS FOR OVERHEAD CONSTRUCTION OF HIGH-TENSION TRANSMISSION-LINE CROSSINGS.

General Requirements.

Drawings.—Complete drawings shall be furnished, in duplicate, for approval before construction is commenced.

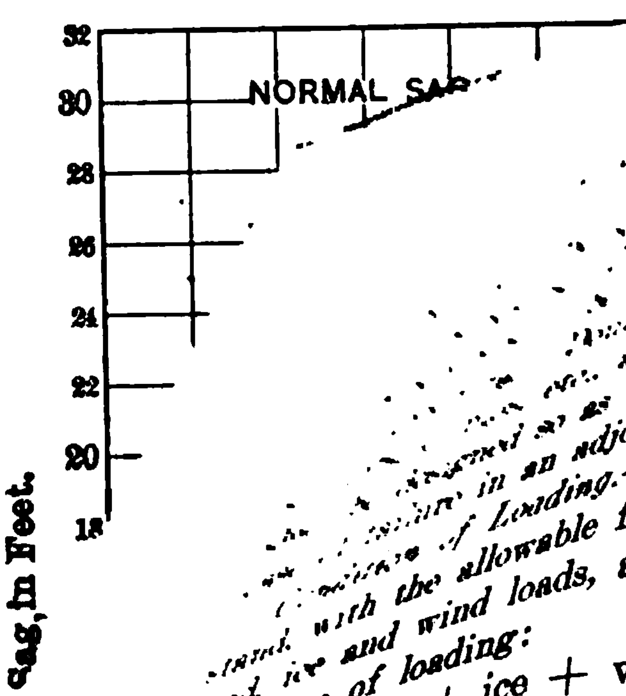
General drawings shall contain full information covering stresses, span, normal sag, size and material of wires or cables, voltage, elevation of the points of support from the top of the rail, and the maximum sag and subsequent clearance above the top of the rail.

Detailed plans, covering insulators, pins, clamps, etc., and their supporting construction and foundations, shall be furnished for approval.

After approval, (..........) complete sets of drawings shall be furnished for file, and, when the construction is at the expense of the Railroad Company, the original tracings shall be forwarded for file.

Clearance.—The clear distance of any part of the construction from the center line of the track, and the clear head-room above the top of the rail, shall be as specified by the proper official of the Railroad Company, but the clear head-room shall not be less than 30 ft. nor less than 6 ft. above any existing wires, such clearance to obtain under the maximum deflection due to loads and temperature.

Minimum spread of wires..................................30 in.
Minimum side or top clearance between wires and superstructure. 15 in.
Minimum side clearance between insulators and superstructure.. 8 in.



... adjoining the crossing span shall ... the ends of crossing spans and ... or be guyed so as to be in effect ... supporting (or an approved substitute), in- ... cross-arms of crossing spans and slack spans ... at the ends to prevent the wires from pulling through in ... as in an adjoining span or at the support.

Loading.—The structure shall be designed to with-stand, with the allowable factor of safety, the combined effect of the dead, ice and wind loads, and be self-sustaining under the following conditions of loading:

(1) Dead + ice + wind on adjoining spans.

(2) Dead + ice + wind on one span and dead load on adjoining span.

Loads.—

Dead load, or weight of the material;

Ice load: Weight of ice ½ in. thick all around exposed members. Weight of ice, 0.033 lb. per cu. in.

Wind load: Wind pressure on wires or other cylindrical surface, 15 lb. per sq. ft. of projected area, such area being taken at the increased figure due to ice ½ in. thick.

Pressure on flat surfaces, 27 lb. per sq. ft.

Factors of Safety.—Factors of safety, under the combination of loads giving the maximum stress, shall be as follows:

Wires and cables	2½
Insulators, pins, clamps, steel cross-arms and connections.	3
Steel superstructure	2¾
Wooden superstructure and cross-arms	5

Temperature.—In the determination of stresses and clearances, and in erection, provision shall be made for a change in temperature of 70° fahr. above and 80° fahr. below a normal temperature of 60° fahr.

Thickness of Material.—All metal in the superstructure shall be not less than ¼ in. in thickness.

Radius of Gyration.—The length of any compression member shall not exceed 150 times its least radius of gyration.

Connections.—Connections, generally, shall develop the full strength of the member, and shall be designed to avoid, as far as possible, induced stresses due to eccentricity.

Net Section.—In calculating tensile stresses, allowance shall be made for reduction in area, due to rivet holes (adding ⅛ in. to the nominal diameter), screw threads, etc.

Rivets.—Rivets shall be machine-driven, wherever practicable. Loose or defective rivets shall be carefully cut out and replaced; if

necessary, to avoid injuring the material, they shall be drilled out. The diameter of the finished rivet hole shall not be more than $\frac{1}{16}$ in. greater than the diameter of the cold rivet.

Bolts.—Bolts shall not be used in place of rivets, except as specified; and when used, the holes shall be reamed and the bolts made to a close fit.

Straightening.—All material, when necessary, shall be carefully straightened at the shop before assembling.

Drainage.—Pockets, such as enclosed column footings, shall have drain holes, and shall be filled with water-proof material (or concrete), or both, as may be required.

Galvanizing.—Messenger and guy wires, insulator pins, clamps, etc., shall be galvanized. Structural-steel poles shall be galvanized in an approved manner, or shall be painted, as provided below.

Painting.—Structural steel shall be thoroughly cleaned at the shops and given one good coat of linseed oil. All surfaces coming in contact in assembling shall be given one coat of approved paint. Parts which will be inaccessible after erection shall receive two shop coats of approved paint. All machined surfaces shall be coated with white lead and tallow. After erection, all steel shall be given two coats of approved paint. Painting shall not be done during rainy weather, or when the surface of the metal is wet. All dirt, cinders, oil blisters, etc., shall be removed before painting.

Weight.—A variation, in section or weight of materials, of more than $2\frac{1}{2}\%$ will be sufficient cause for rejection, except that sheared plates may vary according to the allowances of the Manufacturers' Standard.

Foundations.—The foundations shall be designed to resist overturning, assuming:

Weight of "earth"........................	90 lb. per cu. ft.
" " "concrete"	140 " " " "
Angle of friction of "earth"................	33° with vertical.

Foundations, in general, shall extend above the ground as a protection to the lower part of the structure; otherwise, the depth and spread of foundations shall be governed by the local conditions.

Guys.—Guy wires shall have an efficient anchorage, and be protected, or of extra strength, at the ground level.

Cradles.—Cradles are not to be furnished, but the crossing shall be designed for their possible future installation.

Timber.—All timber shall be of the best quality of the kind and use specified, cut from sound trees, and sawed to size; close-grained and solid, and out of wind; free from defects, such as injurious ring shakes, crooked grain, large, unsound or loose knots, knots in groups, decay, large pitch pockets or other defects which would materially impair its strength.

TABLE 9.—UNIT STRESSES IN MATERIALS, IN POUNDS PER SQUARE INCH.

Material.	Tension.	Compression.	Shear.	Bearing.	Bending.	Compression with the grain.	Compression across the grain.	Transverse shear.	Longitudinal shear.	Columns.
Soft steel	19 000	$\left\{19\,000 - 65\frac{l}{r}\right\}$	12 500	......	......	......	......	......	......	......
Medium steel	22 000	$\left\{22\,000 - 80\frac{l}{r}\right\}$	14 500	......	......	......	......	......	......	.....
Shop rivets and pins..	......	......	12 000	24 000	......	......	......	......	......	.....
Field rivets and bolts..	......	......	9 000	18 000	......	......	......	......	......	......
Pins	......	......	......	......	24 000	......	......	......	......	......
Long-leaf yellow pine.	......	......	......	......	1 200	1 400	300	1 000	150	$\left\{1\,200 - 18\frac{L}{D}\right.$
Oak	......	......	......	.....	1 200	1 400	400	800	16	$\left\{1\,000 - 15\frac{L}{D}\right.$
Chestnut	......	......	......	......	1 000	1 000	180	300	120	$\left\{800 - 10\frac{L}{D}\right.$
Cedar..................	......	......	......	......	950	1 000	150	300	......	$\left\{800 - 12\frac{L}{D}\right.$

TABLE 10.—COMPOSITION, ETC., OF STEEL AND IRON.

Kind of Steel, etc.	Phosphorus, in acid steel, not more than	Phosphorus, in basic steel, not more than	Sulphur, not more than	Ultimate strength, in pounds per square inch.	Elastic limit Percentage	Minimum elongation in 8 in. Percentage.	Minimum reduction in area. Percentage.	Bending.
Medium, open-hearth, structural steel...	0.08%	0.04%	0.05%	60 000 to 68 000	50	22	50	180° cold.
Soft, open-hearth structural steel.......	0.08%	0.04%	0.05%	52 000 to 60 000	50	25	50	cold, 180° flat.
Rivet steel...............................	......	0.04%	0.04%	48 000 to 56 000	55	28	56	quenched, 180°
Open-hearth cast steel, annealed.........	0.08%	0.05%	0.05%	65 000 Minimum.	50	in 2 in. 15	20	cold, 90° diameter = thickness × 3
Cast iron......	......	......	0.10%	See note*	....	......	....	....

* Cast iron, unless otherwise specified, shall be tough, gray iron. It shall be free from flaws and excessive shrinkage. Tests on the "Arbitration Bar" (1¼ in., circular, and 15 in. long), with supports 12 in. apart, shall show a deflection of 0.10 in. for a center load of 2 900 lb.

Each wooden pole or tower shall be set in a concrete base.

Poles shall be of the first quality, with a minimum diameter of 7 in. at the top, and within the following limits of wind:

30 to 40 ft. long	—not more than 3 in.
40 to 50 " "	— " " " 4 "
50 to 60 " "	— " " " 5 "
60 ft. and longer	— " " " 6 "

Cross-arms, bearing surfaces, and the surfaces of notches, etc., shall be treated with paint or preservative.

Adjustment.—The sag given the catenaries at erection shall be adjusted to the temperature of the wires, that is, it shall be that corresponding to the dead-load tension of the given span at the temperature of the wires. Particular care shall be exercised in adjusting insulators, clamps, etc., to obtain the desired distribution of stresses.

Workmanship.—The workmanship on the various classes of construction involved shall conform to the requirements of first-class practice.

Insulators.—One or more insulator units, as may be required, shall be assembled complete and mechanically tested to destruction. Insulators shall be tested in accordance with special instructions to be given. Insulators or caps shall not be connected during freezing temperatures.

Reasonable notices of the proposed tests shall be given the .... and his representative shall be given every facility for witnessing them.

In all cases full test reports shall be forwarded.

CONCRETE.

The proportions of the materials in the concrete shall be as called for on the drawings, and the proportioning and methods of mixture shall be as required by the Engineer.

Cement.—All cement used in the work shall be of an approved brand of Portland cement. The specific gravity of the cement, thoroughly dried at 100° cent., shall not be less than 3.10. It shall leave, by weight, a residue of not more than 8% on the No. 100 and not more than 25% on the No. 200 sieve.

It shall develop initial set in not less than 30 min., but must develop hard set in not less than 1 hour nor more than 10 hours.

Tensile Strength.—The minimum requirements for tensile strength for briquettes 1 in. square in section shall be within the following limits, and shall show no retrogression in strength within the periods specified:

Neat cement:

24 hours in moist air	150 to 200 lb.
7 days (1 day in moist air, 6 days in water)	450 to 550 "
28 days (1 day in moist air, 27 days in water)	550 to 650 "

One part cement, three parts sand:

7 days (1 day in moist air, 6 days in water) 150 to 200 lb.
28 days (1 day in moist air, 27 days in water) ....200 to 300 "

Constancy of Volume.—Pats of neat cement about 3 in. in diameter, ½ in. thick at the center and tapering to a thin edge, shall be kept in moist air for a period of 24 hours.

(*a*)—A pat is then kept in air at normal temperature and observed at intervals for at least 28 days.

(*b*)—Another pat is kept in water maintained as near 70° fahr. as practicable, and observed at intervals for at least 28 days.

(*c*)—A third pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely-closed vessel, for 5 hours.

These pats, to pass the requirements satisfactorily, shall remain firm and hard, and shall show no sign of distortion, checking, cracking or disintegrating.

Sulphuric Acid and Magnesia.—The cement shall not contain more than 1.75% of anhydrous sulphuric acid (SO_3), nor more than 4% of magnesia (MgO).

Sand.—All sand shall be hard, clean, coarse and sharp, and shall not contain more than 1.5% of clay or other foreign matter. If required by the Engineer, it shall be screened.

Stone.—All stone shall be sound, hard, and durable, and free from dirt and foreign matter, and shall pass through a ring 1½ in. in diameter.

Consistency.—The degree of moisture for mortar, grout and concrete shall be as required by the Engineer; in general, mortar shall be plastic, grout fluid, and concrete of such consistency that it will quake when being deposited.

Mortar, grout, or concrete which has commenced to set shall not be used in the work.

Placing.—Concrete shall be deposited in the work so that there shall be no separation of mortar or stone. It shall be laid quickly in layers, and spaded as may be required. Rock surfaces shall be thoroughly cleaned, and earth surfaces shall be compacted in a satisfactory manner, before concrete is deposited against them. Surfaces of concrete against which fresh concrete is to be laid shall be cleaned and slushed over with grout, and shall be provided with a bond if required by the Engineer.

Forms.—Forms shall be of substantial construction, and designed to preserve the concrete in the form required by the drawings. All exposed surfaces of concrete shall be true to form and surface.

General Clauses.

1.—Every facility for the inspection of materials and workmanship shall be furnished by the contractor; he shall furnish proper testing apparatus, and shall prepare and test such specimens as may be required.

2.—All work shall be subject to the inspection and approval of the Railroad Company's Engineer, and his interpretations of the drawings and specifications, and his decisions as to the quantity or quality of the work, shall be final and conclusive.

3.—The contractor shall remove all falsework, timber, or rubbish incident to his operations, and shall leave the site unobstructed and clean.

4.—The contractor shall bear the cost of any suit which may arise, and shall pay all damages which may be awarded in consequence of the use by said contractor of any patented device in the construction of any work under these specifications.

5.—The contractor shall obtain all necessary permits, and shall assume all risk of accidents to men or materials prior to the acceptance of the finished structure.

Overhead Construction for Electric Traction.

The adoption of electric traction, under the operating conditions prevailing on the present steam roads, introduces a demand for a more substantial type of construction than was necessary for the so-called trolley lines.

Short spans with many supporting poles near the tracks are objectionable in appearance, are a menace to train hands, and are likely to be injured by derailments. With four or more tracks, at standard spacing, poles between tracks will rarely be permitted in the United States, though such an arrangement has been used abroad. Similarly, the superstructures must be self-supporting, or be free from guys parallel to the track. Guys at right angles to the track may be permitted in some localities, but may not be allowable in others, on account of a limited right of way.

Assuming, for present purposes, that men must be permitted to stand on the tops of cars, and that overhead clearance must be given for wrecking cranes and at public crossings, the following clearances must be maintained:

Minimum clear headroom from top of rail to trolley wire..	22 ft.	0 in.
" " " " " " " " power " ..	22 "	0 "
Minimum clearance from center line of main track.......	9 "	6 "
" " " " yard running track.....	8 "	6 "
" " " " yard standing track.....	8 "	0 "

Superstructures may be divided into three classes:

(1)—Two posts or bents supporting a transverse span wire;
(2)—Two posts or bents supporting a transverse truss;
(3)—Single post or bents supporting cantilever brackets.

Of these, the first has been used on various interurban roads, while the recent New York, New Haven and Hartford Railroad installation is the most prominent illustration of the second. The third, which is a heavy type of the present trolley line construction, has not been used in the United States, though it is now in use in Germany, Switzerland and Italy, under more favorable operating conditions than generally obtain on steam roads in America.

Comparing Classes 2 and 3, the former has the following advantages: It has greater rigidity and strength, is better adapted to the erection of catenaries, and permits the telegraph and telephone cables to be widely separated from the power wires. On the other hand, Class 3 offers less obstruction along the tracks, with decreased probability of injury from derailment; less interference with stations, platforms, etc., and permits the addition of tracks without alteration of existing construction.

While two-track bridges can be made comparatively shallow, the depth necessary for four tracks becomes great enough to be an obstruction to the view of upright signals, and the foreground of intermediate trusses will obscure the engineer's view at approximately 1 200 ft.

Catenaries, or the supporting spans for the conductor, are of two general classes: "single," having one messenger cable, with or without an intermediate or "secondary" cable; and "double," in which the conductor is hung by triangular hangers from a pair of messengers. The former type is merely the interurban trolley construction on a larger scale, while the advocates of the latter consider greater rigidity desirable. Up to the present time, these two types have not been suf-

ficiently tested by operation under severe conditions to make possible a definite decision in favor of either. Subject to the successful operation of the trolley pole or pantagraph frame, in connection with the more flexible single catenary, the writer believes the single catenary to be the better type. The single catenary presents a better appearance, offers less obstruction to the view of signals, and costs less, both in original cost and maintenance. It will be found advisable to avoid

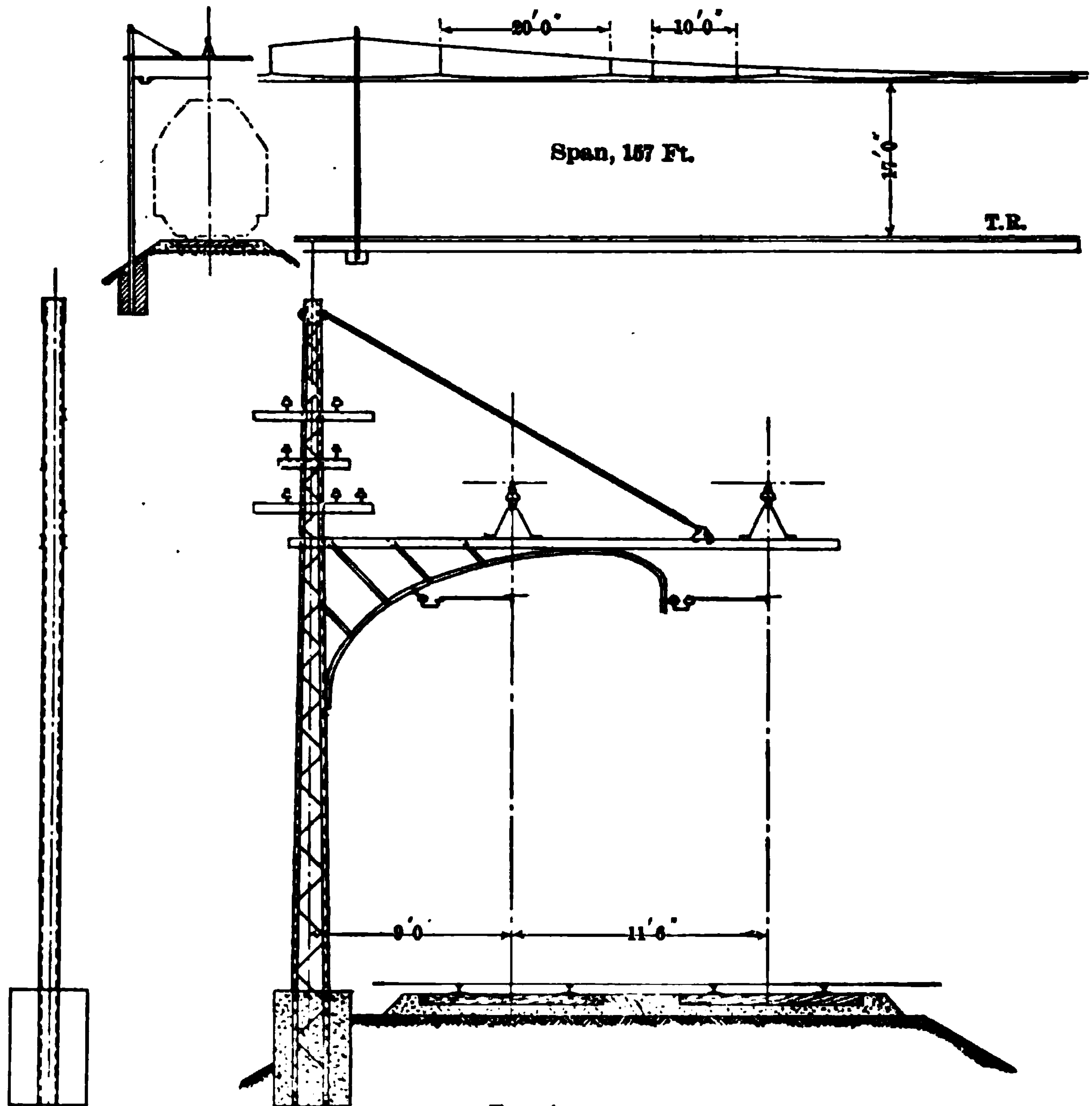


FIG. 4.

many small parts, particularly those of thin section, in catenary construction, inasmuch as, while the need of maintenance should be small, the cost will be relatively high. Work on the ground can be done much more cheaply and easily than that necessitating a work train with telescoping platforms and a right to use the track.

Fig. 4 shows the construction used on several foreign roads.

Catenaries.—The catenary construction is composed of a main messenger cable, from which is hung a secondary messenger, from which in turn the trolley wire is suspended. The main messenger consists of a single catenary about $\frac{3}{8}$ in. in diameter, of 7-strand, high-tension steel, the normal stress being about 1 100 lb., with an ultimate strength of 11 000 lb., or about 140 000 lb. per sq. in. The secondary messenger is a solid steel wire having a diameter of about 0.236 in., a normal tension of about 220 lb., an ultimate strength of 6 200 lb., or about 140 000 lb. per sq. in. The trolley wire is grooved, hard-drawn copper, having an area of about 0.155 sq. in. (approximately No. 0000 trolley wire), with an ultimate strength of 8 800 lb., and maintained at a normal tension of about 1 100 lb. by counterweights at intervals of about 1 mile.

The hangers attaching the trolley wire to the secondary messenger are about 6 in. long, and are looped over the messenger, but not fastened to it. There is an allowance of 2 or 3 in. in the loop, so that the trolley wire and hanger can rise vertically, for 2 or 3 in., without raising the messenger. The hanger itself is rigid, and grips the groove in the trolley wire. Counterweights, maintaining constant normal tension in the trolley wire, are spaced at intervals of about 1 mile, at which points the trolley wires lap past each other at an anchor span, each wire passing around pulleys and being attached to counterweights at the post. This arrangement is also used as a combination section-break.

Catenaries are zigzag to the center line of the track, with a displacement of about $\frac{1}{2}$ m. per span between the ends. Care is taken to erect catenaries with the center of the span on the center line of the track, in order to prevent the trolley wire from approaching too close to the ends of the pantagraph bow.

Turnouts are of simple design, having no additional contact wires (gridiron). Turnout catenary and trolley wires are independent spans, and are pulled over into position adjoining the main span. Pull-off posts are used at curves, and the main spans are not reduced on account of curvature. Steady strains are placed at each post, and have an adjustable connection to the short hanger between the secondary messenger and the trolley wire.

The support for the main messenger insulators is of light construction, and is not designed to resist an unbalanced pull. This construction will be made stronger in future work.

The advantage claimed for a catenary of this type, apart from the reduced cost, is extreme flexibility. The counterweighted trolley wire is maintained at constant tension, while being free to move vertically, and therefore presents fewer hard spots against the pressure of the trolley. If the trolley wire tension and the pressure from the bow are carefully adjusted, the wire might be said to hang from the bow and be free to move up and down, within limits, while being supported locally by the passing shoe.

Superstructure.—The superstructure consists of two-track cantilever brackets having a guy from the outer end of the bracket to the top of the post. The posts also carry seven power wires, and are composed of two channels with flanges turned inward, with single lacing between the webs of the channels. The cantilever bracket is a horizontal arm with a long curved knee-brace, light channels being used for both members. The post channels are embedded in the concrete foundation. The entire construction is very light, and is not capable of resisting unbalanced loads or broken wires without distortion and without depending on adjoining wires exerting a supporting reaction.

Dimensions.—

Main span	157 ft. 0 in.
Distance of trolley wire from top of rail	17 " 0 "
Distance from center to center of tracks	11 " 6 "
Distance from center of track to center of post	9 " 0 "
Intermediate span of secondary messenger (space between hangers)	20 " 0 "
Distance between trolley wire hangers	10 " 0 "

Operation.—Pressure of bow .... 12 lb.

Voltage 6 600

Two trolleys are used on each motor car, and, as the overhead construction is very flexible, the bow maintains contact at all times, although it can, and does, deflect the trolley wire vertically. No trouble has been experienced in running past turnouts at a speed of 60 miles per hour, and it is confidently expected that there will be no trouble at higher speeds. The contact shoe lasts for about 4 000 miles.

On the Midland Railway, England, and on other foreign roads, a type of construction similar to the foregoing, but with the following modifications, is about to be installed:

Length of span.................................. 100 m.
Sag .... 3 m.
Main messenger—7-strand, high-tension steel; 65 sq. mm.; ultimate strength, 100 kg. per sq. mm. (0.1007 sq. in., or 140 000 lb. per sq. in.).
Secondary messenger—solid steel wire; 6½ mm. in diameter; ultimate strength, 100 kg. per sq. mm. (0.0514 sq. in., or 140 000 lb. per sq. in.).

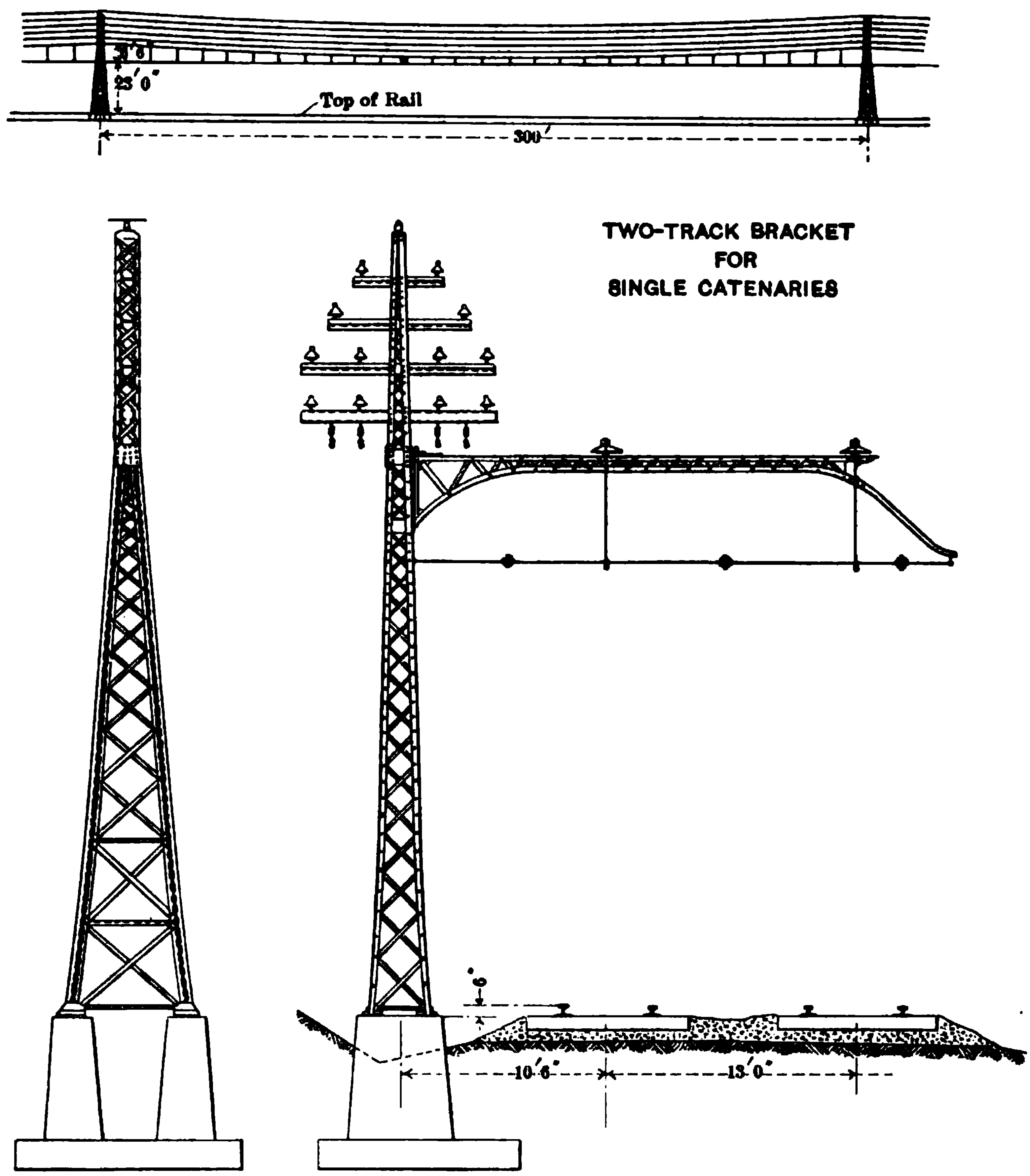


FIG. 5.

Superstructures are to be preferably of the bridge type, instead of cantilever brackets, the overhead "trusses" being light beams (probably channel construction) with supporting guys to the top of the

A-frame posts, and with intermediate posts between the tracks where a number of additional tracks are spanned.

The main catenary insulator supports will be strengthened, and the construction will consist of an insulator supported by the "truss," with

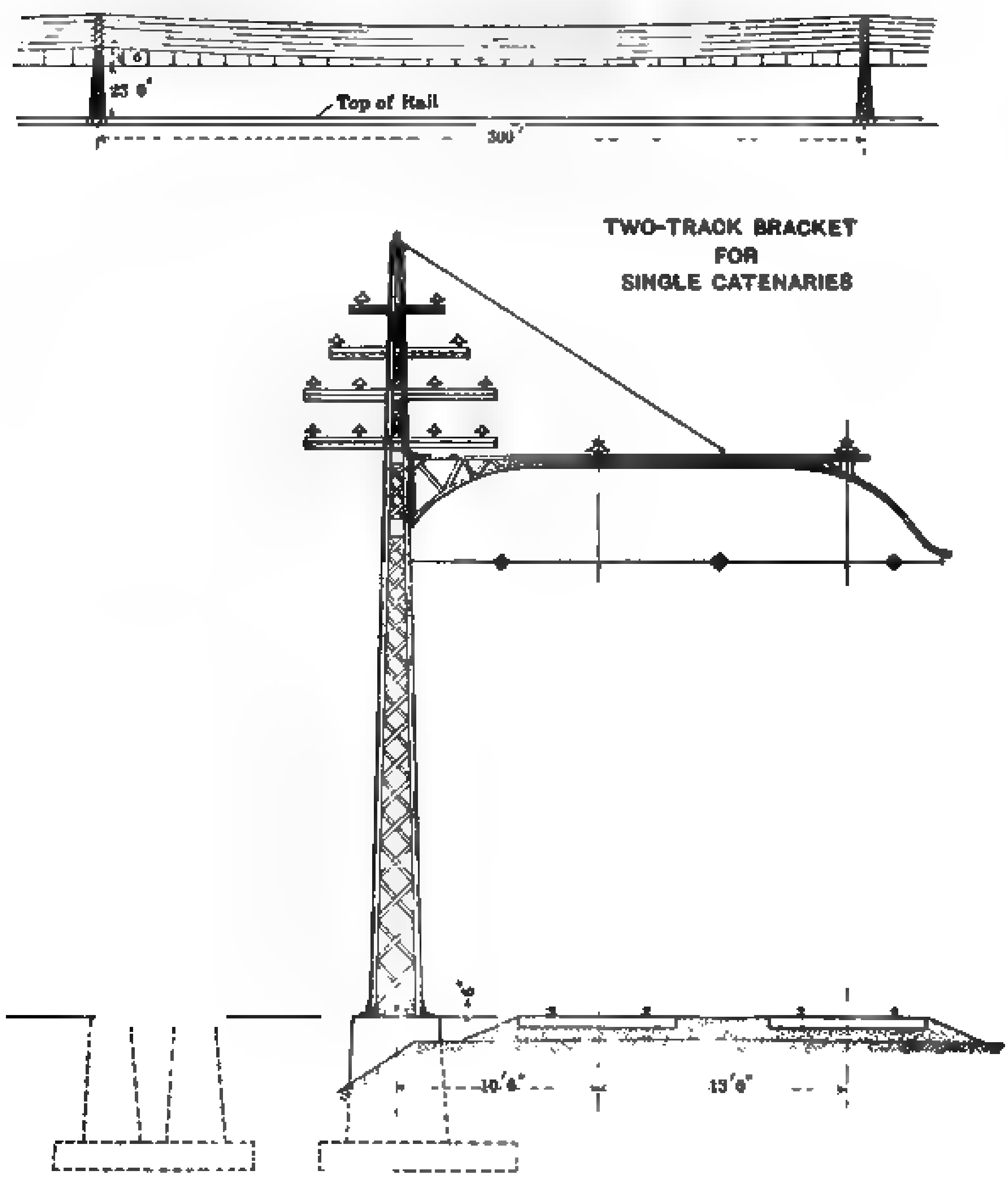


FIG. 6.

a gooseneck carrying another insulator projecting on each side. The main messenger wire will be dead-ended on the insulators at the outer end of the gooseneck.

The writer suggests the types of construction shown in Figs. 5, 6, 7 and 8. As will be noted, these designs are arranged to carry heavy power, telegraph and telephone lines, and may be of two types:

(1).—Cantilever brackets at intermediate points, with anchor and signal bridges spaced about 3 000 ft. apart.

(2).—Bridges for both intermediate and anchor supports.

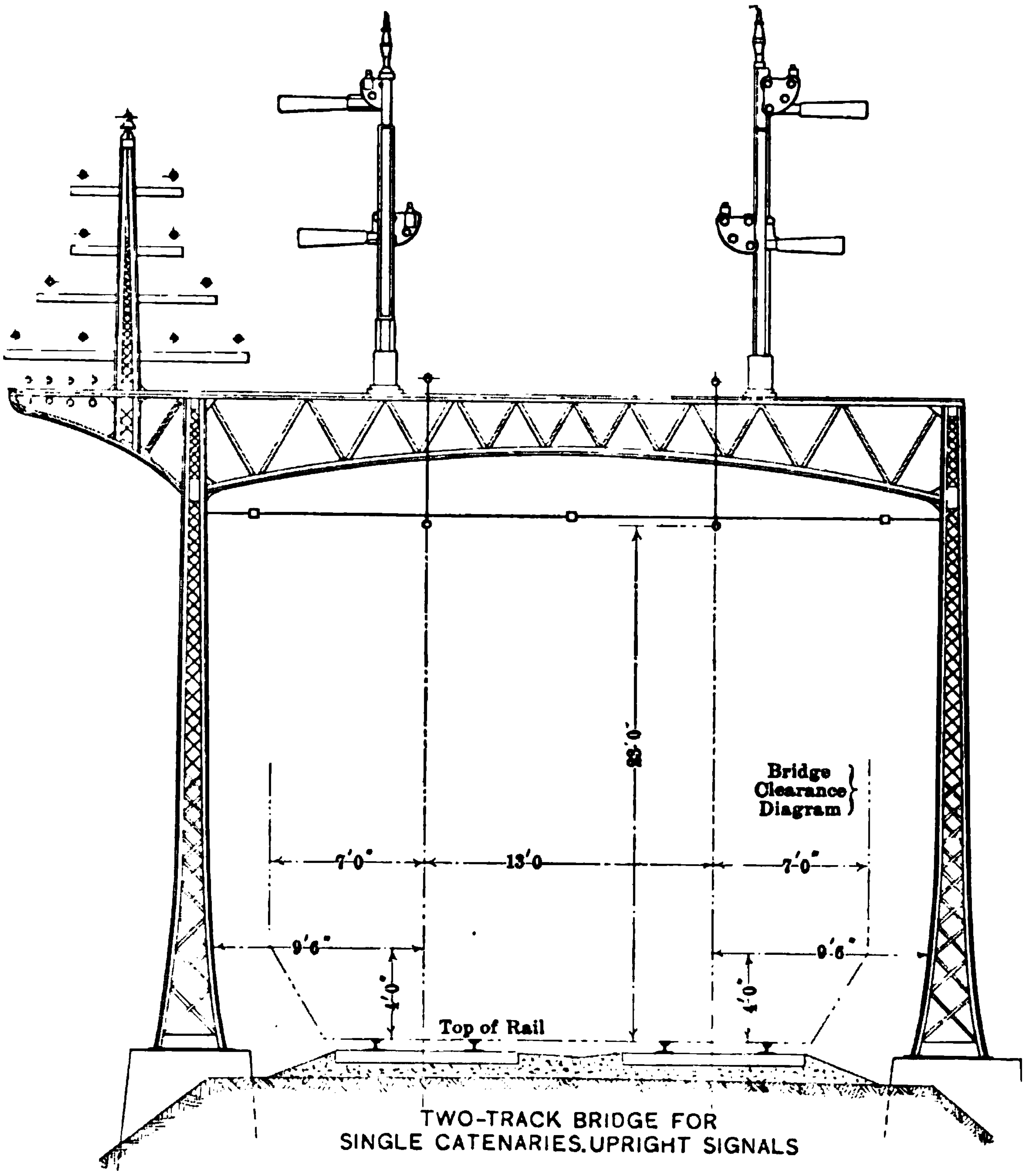


FIG. 7.

GENERAL DATA.

Spans of 300 ft.,
Single catenaries,
Signal and anchor bridges spaced 3 000 ft. apart,
Power wires (250 000 cm.), stranded copper,
Two 40-pair telephone cables,
Two 25-wire telegraph cables,
No. 0000 trolley wire,
Voltage, 11 000.

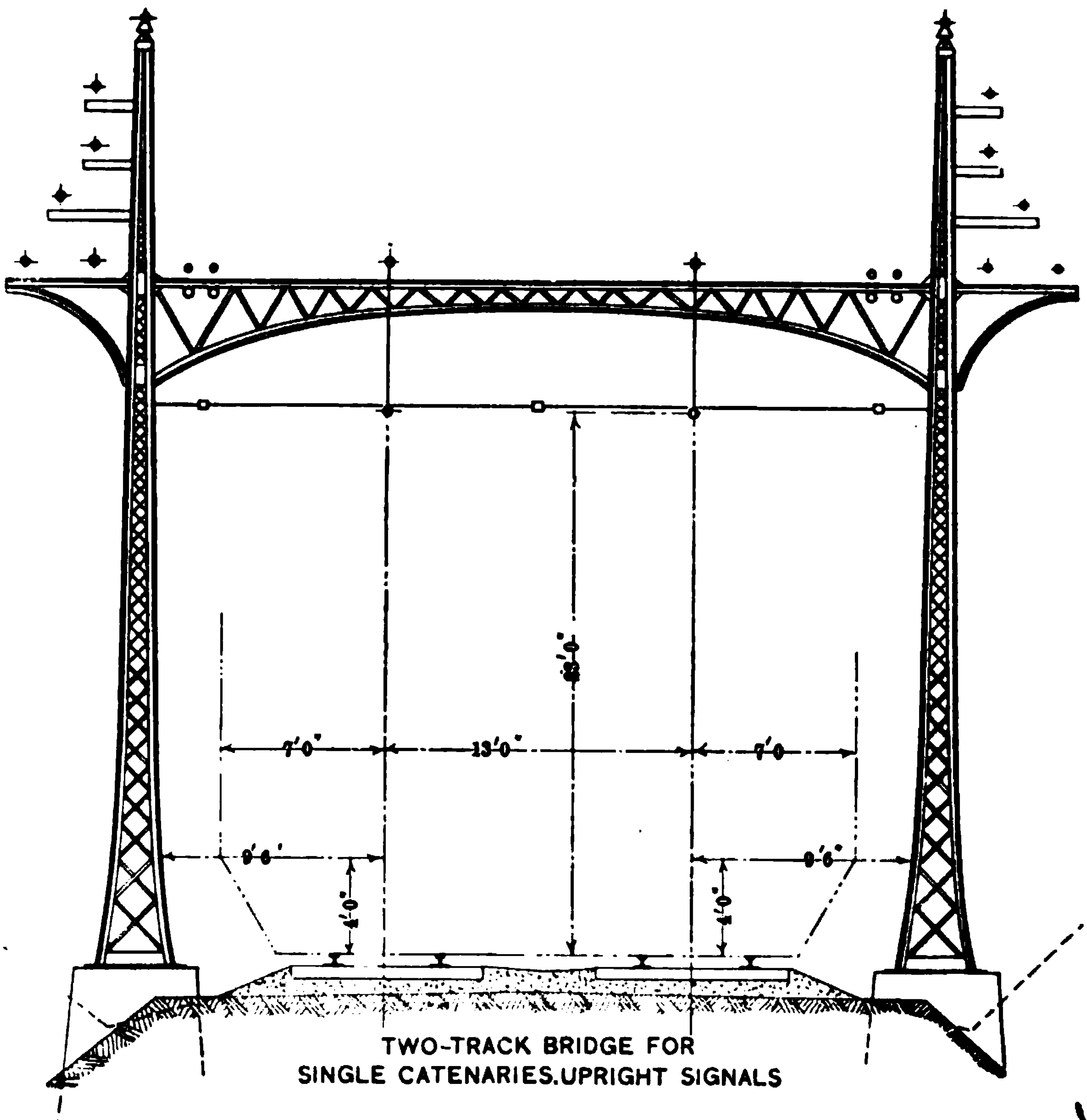


FIG. 8.

Clearances.—

Minimum clearance, top of rail to trolley wire	22 ft. 0 in.
" " " " " " power wires	22 " 0 "
" " " " " " telegraph or telephone cables	22 " 0 "
(except at overhead street bridges, etc.)	
Minimum spacing, center to center of power wires	2 " 6 "
Minimum uninsulated clearance between wires and superstructure	1 " 3 "
Minimum side clearance between insulators and superstructure	0 " 8 "

Minimum Side Clearance from Center of Track.—

Main-line track	at top of rail	9 ft. 0 in.
	4 ft. or more above rail	9 " 6 "
Yard running track	at top of rail	8 " 0 "
	4 ft. or more above rail	8 " 6 "
Yard standing track	at top of rail	7 " 6 "
	4 ft. or more above rail	8 " 0 "

Ice Load.—Ice ½ in. thick all around exposed members; weight of ice 0.033 lb. per cu. in.

Wind Load.—

8.0 lb. per sq. ft. of projected area of ice-covered wires.
12.0 " " " " of projected area of wires without ice.
20.0 " " " " on flat surfaces.

Conditions of Loading.—

(1).—Dead + ice + 8 lb. wind on adjoining spans.
(2).—Dead + ice + 8 lb. wind on one span; and dead + ice + 2 lb. wind on adjoining spans.
(3).—Dead + 12 lb. wind on one span, and dead + 4 lb. wind on adjoining spans.
(4).—Dead + ice on one span, and dead on adjoining spans.

Factors of Safety.—

Trolley messengers	3
Telegraph and telephone messengers	2
Power wires	2½
Ground wires	2½
Steel superstructure	2⅔
Insulator pins	3

Ground Wire.—A suitable galvanized, stranded steel wire shall be suspended parallel to and over the group of power wires. The ground wire need not be at the apex of a 60° angle enclosing all the wires.

Thickness of Material.—The metal in all steel superstructure shall be not less than ¼ in. in thickness.

Temperature.—Provision is to be made in the determination of stresses and clearances, and in erection, for a change in temperature of 70° fahr. above and 80° fahr. below a normal temperature of 60° fahr.

Bolts.—Bolts are not to be used in place of rivets, except as specified, and when used the holes are to be reamed and the bolts made to a close fit.

Galvanizing.—Messenger wires, guy wires, clamps, insulator pins, etc., are to be galvanized in an approved manner.

Unit Stresses.—

Tension		22 500 lb. per sq. in.
Compression		22 500 lb.—82 $\frac{l}{r}$
Shear:	Shops rivets and pins	12 000 lb. per sq. in.
	Field rivets and bolts	9 000 " " " "
Bearing:	Shop rivets and pins	24 000 " " " "
	Field rivets and bolts	18 000 " " " "
Bending:	Pins	24 000 " " " "
Bearing on concrete foundation		350 " " " "

Design.—If necessary to an economical design, it would be logical to assume higher unit stresses to apply to the case of broken wires, such incidents being presumably of very rare occurrence. It seems to be unreasonable to design the entire line with the normal factor of safety for a condition that will certainly never occur on the whole line, and may never occur on any of it.

It is assumed that the trolley messenger cables, having a factor of safety of 3 under maximum loading, will not break except when burned, and that such burning will not occur under ice and wind load. The result of such an accident would be to rotate the brackets, break some insulator clamps, and probably stop traffic on one 3 000-ft. section, but not to cause failure of the steel superstructure.

The connection of telephone and telegraph cable messengers should be made by swinging hangers, which will allow alterations of adjoining span lengths, and thereby balance unequal tensions in adjoining spans.

Cantilever brackets supporting catenaries should be designed with pivoted or pin-ended connections in order to permit a horizontal motion of the brackets, and balance any unequal tension in the adjoining catenary spans.

The condition of unequal loading on adjoining spans, due to localized ice or wind loading, does not appear to have been considered by all designers. The conditions of loading given in the specifications, which include a reasonable unbalanced loading, will certainly occur, and should be considered. By a careful arrangement of outline, swinging connections for telephone and telegraph cables, and a small amount of post deflection, the effect of this unbalanced loading on the steelwork may be reduced to approximately the same amount as that of ice and wind on two adjoining spans, which condition of loading is generally accepted.

Superstructures.—The form of the steel supports will depend on local conditions and the line requirements, and may properly be bridges, cantilever brackets, or span wire construction, and may be either built sections or pipe construction.

Foundations.—All foundations should be of concrete.

Trolley Catenaries.—Catenaries, namely, the self-supporting spans of trolley wire, or the supporting spans for a non-self-supporting trolley wire, are of three general classes:

(1).—"Simple catenary," or span of trolley wire;

(2).—"Single catenary," having one supporting messenger cable, with or without an intermediate or secondary messenger;

(3).—"Double catenary," in which the trolley wire is hung by triangular hangers from a pair of messengers.

Simple catenaries, of the type now in use on the various trolley roads, are only available for short spans, because the copper trolley wire cannot withstand the stresses of long spans with small sag. By a modification of the ordinary hanger, Joseph Mayer, M. Am. Soc. C. E., has designed a type of simple catenary which, it is claimed, reduces the stresses in the wire to allowable units.

Simple catenaries and single catenaries, unless provided with lateral guys, are subject to criticism on the score of lateral displacement from wind pressure. Such displacement, in amount sufficient to carry the

trolley wire beyond the range of the contact bow, can only occur locally during severe wind storms. If, however, a locomotive should be in a given span during such displacement, the contact bow would probably rise above the wire and, catching above it, be torn off.

Double catenaries seem to the writer to be less desirable than the foregoing types, for the following reasons:

(1).—Greater first cost of catenaries, insulators, and supporting steelwork;

(2).—More members to maintain, and these of a construction more difficult to maintain;

(3).—Greater mass of material above the tracks, with more unsightly appearance;

(4).—More obstruction to the view of signals, and to the location of signal posts;

(5).—The greater rigidity of the trolley wire does not seem to be a point in favor of double catenaries, but, on the contrary, to cause sparking at the contact bow.

Assuming, then, that either "simple" or "single" catenaries are desirable, it becomes necessary to determine which one of the following types is best suited to meet the conditions of first-class traffic:

(1).—Simple catenary (Mayer's saddle suspension);

(2).—Single catenary;

(3).—Single catenary with secondary messenger (German method).

The writer does not consider that, as yet, a definite decision can be made in favor of any one type, particularly as the result of experience under actual operating conditions is the only satisfactory proof. It is not necessary to obtain some saving in first cost, which must be relatively slight, but it is very important to obtain a construction fulfilling certain requirements.

The maximum stresses in catenary or trolley wire produced by ice and wind loads, temperature changes, or the pressure of the contact bow at high speeds, should not exceed a safe percentage of the elastic limit of the material. There should be sufficient lateral and vertical rigidity to prevent undue displacement from the pressure of the contact bow. The weight, sag, and factor of safety may be chosen so as

to reduce somewhat the likelihood of lateral displacement from wind pressure, otherwise the relative importance of providing lateral rigidity is to be considered.

The trolley wire should have some flexibility, in order to maintain contact with the collector shoe, unless, as seems improbable, a support for the collector shoe can be devised which will adjust itself to all inequalities in the trolley wire. It will be necessary to eliminate, as far as possible, the formation of "hard spots" in the trolley wire, due to the hangers. Local bends may be the cause of sparking, whether they are formed during erection, or by displacement, or by the contact pressure. Simple details, readily replaced, and avoiding the use of thin metal sections, will materially reduce the cost of maintenance.

A successful type of catenary should be adapted to changes in elevation caused by overhead street bridges, without introducing marked differences in the action of the contact bow against the trolley wire.

Pantagraph, or Supporting Frame for the Collector.—There is a very close relationship between the characteristics of a trolley wire and those necessary in a pantagraph frame which will work successfully on that wire.

The use of two pantagraphs, or two collectors, per locomotive will materially reduce trouble from sparking, simultaneous jumping of both contacts being improbable.

The ideal type of pantagraph or supporting frame would be one having rigidity against lateral and longitudinal wind pressure, simplicity of construction, flexibility, little mass or equivalent weight pressing against the trolley wire, and at the same time the ability to maintain contact.

Aside from the sparking at the contact, the possible wear on the trolley wire and on the pantagraph frame, a successful design should keep the wear on the contact shoe within reasonable limits.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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A NEW SUSPENSION FOR THE CONTACT WIRES OF ELECTRIC RAILWAYS USING SLIDING BOWS.

By Joseph Mayer, M. Am. Soc. C. E.
To be Presented February 5th, 1908.

For high speeds and the high voltages generally used with them, the ordinary trolley wire suspension has proved unsatisfactory. Single or double catenary suspensions, therefore, have largely taken its place. They permit the use of longer spans, and thereby diminish the number of poles, brackets, and insulators.

With single catenary suspensions, spans of 120 to 150 ft. are mostly used. In these the contact wire is suspended at short intervals from a galvanized steel strand above, and is approximately straight and of the same length at all temperatures. Cold weather, therefore, greatly increases its tension. The amount of increase depends on the modulus of elasticity and the coefficient of expansion of the wire.

The modulus of elasticity of copper wire varies considerably. For very hard wires, it is given as high as 20 000 000 lb. per sq. in.; for moderately hard wire, such as is commonly used for contact lines, Mr. Blackwell gives 16 000 000 lb. as a fair average. The coefficient of expansion for changes of temperature is $\frac{1}{104\,400}$ per degree Fahren-

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

heit. The change in tension per square inch, per degree Fahrenheit, in a wire of constant length, therefore, is 191.5 lb. in the former, and 153.2 lb. in the latter case.

For 140° variation of temperature, the change in tension per square inch is 26 810 lb. in the former, and 21 450 lb. in the latter case. To avoid this variation in the tension of the contact wire, an automatic adjustment of its length has been adopted on the line, Blankenese-Ohlsdorf, near Hamburg, Germany, recently opened for traffic.

If the contact wire is firmly held by rigid suspenders without hinges, the sliding bow which rises between succeeding suspenders bends the wire in a rather sharp curve as it approaches them. At the suspenders this curve is convex downward. To prevent the jumping of the sliding bow at these curves, it must be very light, and the wire must be under high tension. At a speed of 75 miles per hour the sliding bow, with suspenders 10 ft. apart, must make eleven complete up-and-down oscillations per second. With such rapid oscillations, even if they are of very small amplitude, it is very difficult to prevent jumping and sparking; it is impossible, without springs between the bow and its heavy supporting frame, unless the bow itself is a spring.

The bending strains in the wire at the suspenders are also objectionable. To avoid large deflection of the contact wire by the pressure of the sliding bow, its minimum tension in summer must be considerable. The tension in winter is then very large. To this must be added the bending strains arising from the deformations caused by wind pressure, changes of temperature and the pressure of the sliding bow. At high speed the latter is very variable because the bow oscillates rapidly. The consequent bending strains in the contact wire are greatly reduced, in the Blankenese-Ohlsdorf line, by the use of a supplementary steel wire some distance above and parallel with the copper contact wire. The contact wire is hung by loops 3 m. apart from this steel wire, and can rise at these loops, thus permitting the wave raised by the sliding bow to pass unhindered.

The supplementary wire, which, like the contact wire, is nearly horizontal at all temperatures, is carried by suspenders, at intervals of 6 m., from a steel strand above having considerable deflection. The contact wire is grooved, and 100 sq. mm. in cross-section, the steel wire is 6 mm. in diameter, and the steel strand above is of seven

wires, having a total cross-section of 350 mm. With a small contact pressure, the lifting of the wire by cross winds and the passing sliding bow may not be sufficient to permit the latter to touch the supplementary wire and the suspenders. The whole design is ingenious, but complicated and expensive to install, and probably troublesome to maintain. It shows a clear appreciation, resulting from past experience, of the main defects of the catenary suspensions, namely, the excessive tension in the contact wire in winter, the large bending strains in the wire at the suspenders produced by the sliding bow, and the jumping of the latter.

The details of the automatic adjustment of the tension of the contact wire by counterweights are complicated, due to the necessity of insulation, and the impossibility of running the wire over pulleys of moderate size without excessive bending strains. The writer is not aware that such details have been published. The spans of the carrying strand are 48 m., and steady braces are used at the brackets to prevent any lateral deflection of the contact wire there. Large bending strains in the contact wire, at these points and probably at the automatic adjustment of its length, due to lateral deflection by wind pressure, are inevitable. That such complicated and expensive contrivances have been adopted, in the country having the longest experience with catenary suspensions, proves that the much simpler structures previously in use have not been satisfactory even with the moderate speeds used thus far. This is also confirmed by the recent adoption of very short spans without ropes, but with two wires per phase, tied together at short intervals, for the approaches of the Simplon Tunnel.

Since the adoption of steel strands for carrying the contact wire leads to such complicated contrivances, it is worth while to search for a simpler solution of the problem. A clear statement of it will be helpful for the purpose.

The contact wire serves as the track for a rapidly moving sliding bow. It cannot be straight because it must pass at an elevation of [illegible] at an elevation of about 24 [illegible] the range of a [illegible] however, must [illegible]

force and consequent variation of the contact pressure. The amount of centrifugal force is proportional to the square of the train speed and to the weights of the parts of the sliding bow and its supporting frame moving in curves, and inversely proportional to the radii of curvature of their motion. Where the curvature of the motion of the sliding bow is convex upward, the contact pressure is increased; where it is convex downward, it is reduced. The increase, if acting on the wire, should not be large enough to produce dangerous bending strains, and the reduction should not produce interruption of contact and consequent sparking.

The contact wire is exposed to tensions and bending strains, produced by weights, wind pressures, pressure of the sliding bow, and changes of temperature. The sum of these should never, and nowhere, exceed a safe limit. These ends should be attained by the simplest possible means. Simplicity demands the use of long spans, and these require large deflections in the contact wire for preventing excessive tensions. With large vertical deflections, strong winds produce large horizontal deflections. The length of the practicable sliding bow fixes the permissible horizontal deflection. Large and round wires are deflected less by wind than small and grooved wires. The permissible vertical deflection, therefore, is influenced by the practicable length of the sliding bow and the shape and size of the wire. Drop of temperature shortens the wire, reduces its deflection, and increases its tension; it thereby reduces the safe span.

An adjustment which will lengthen the wire in winter will evidently permit the safe use of longer spans. Large deflections result in steep terminal slopes of the contact wire, and a large variation of this slope is produced by changes of temperature and by the lifting of the wire by the passing sliding bows. The large lateral deflections produce large lateral slopes of the wire at the clamps. If the wire leaves the clamps in a fixed direction it will be bent up and down by changes of temperature and the passing sliding bows, and to the right and left by cross winds. This bending of the wire at the ends of the clamps results in bending strains which are large in long spans and are the principal reason why such spans are impracticable with ordinary clamps.

If long spans are to be used with safety, these strains must be reduced. Due to the variable vertical terminal slope of the wire, the

wires, having a total cross-section of 350 mm. With a small contact pressure, the lifting of the wire by cross winds and the passing sliding bow may not be sufficient to permit the latter to touch the supplementary wire and the suspenders. The whole design is ingenious, but complicated and expensive to install, and probably troublesome to maintain. It shows a clear appreciation, resulting from past experience, of the main defects of the catenary suspensions, namely, the excessive tension in the contact wire in winter, the large bending strains in the wire at the suspenders produced by the sliding bow, and the jumping of the latter.

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Since the adoption of steel strands for carrying the contact wire leads to such complicated contrivances, it is worth while to search for a simpler solution of the problem. A clear statement of it will be helpful for the purpose.

The contact wire serves as the track for a rapidly moving sliding bow. It cannot be straight because it must pass at an elevation of about 16 ft. under overhead crossings and at an elevation of about 24 ft. over grade crossings. The horizontal curvature gives no trouble in this respect, as long as the wire does not pass beyond the range of a sliding bow of moderate length. The sliding bow, however, must follow the vertical curvature of the wire. This results in centrifugal

force and consequent variation of the contact pressure. The amount of centrifugal force is proportional to the square of the train speed and to the weights of the parts of the sliding bow and its supporting frame moving in curves, and inversely proportional to the radii of curvature of their motion. Where the curvature of the motion of the sliding bow is convex upward, the contact pressure is increased; where it is convex downward, it is reduced. The increase, if acting on the wire, should not be large enough to produce dangerous bending strains, and the reduction should not produce interruption of contact and consequent sparking.

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If long spans are to be used with safety, these strains must be reduced. Due to the variable vertical terminal slope of the wire, the

sliding bow approaches the clamp with a variable upward slope of its motion. It should pass the clamp along a curve of large radius tangent to this variable slope of approach. This is not practicable if the wire leaves the clamp in a fixed direction.

The reduction of the bending strains in the contact wire at the clamps and the creation of a smooth track, of large curvature, at all temperatures, for the sliding bow is obtained by the suspender shown on Plate CXI. It consists of four castings firmly bolted together and provided with a central ear for attaching it to an insulator pin. The wire is firmly held in the central part of the suspender. It leaves this central part 8 in. long with vertical slopes of 3% below the horizontal. The suspender is designed for 240-ft. spans of 000 B. & S. gauge wire, with 2½ ft. maximum vertical deflection. It is intended for use on a line having maximum train speeds not exceeding 80 miles per hour.

The variation of temperature is assumed at 140° fahr. Strain adjusters, one mile apart (to be described later) in effect reduce this variation to 84° fahr. The central part of the suspender encloses the wire. The sliding bow moves here, along the bottom of the suspender, along an arc of a circle having a radius of 11 ft. 1⅓ in. Where the wire leaves the central part, its bottom is tangent to the bottom of the suspender. Next to the central part of the suspender are two channels, open below. These channels have top walls which, in effect, are horizontal cylinders of 75 ft. radius. The top walls are tangent to the top of the wire where it leaves the central part. The walls are recessed, for easier manufacture. The side walls, which are only 14 in. long, are vertical cylinders of 70 ft. radius. They are tangent to the sides of the wire where it leaves the central part. Below these terminal channels of the suspender the sliding bow moves along the bottom of the wire. The lower edge of the side walls, for all positions of the wire, is above its bottom, so that the side walls will not interfere with the sliding bow. On curves, the suspender is hung with its bottom parallel to the plane of the track.

The wire is assumed to have an ultimate strength of 50 000 to 60 000 lb. per sq. in. and an elastic limit of 40 000 to 45 000 lb. The modulus of elasticity is assumed at 16 000 000 lb. With these assumptions, the largest tension in the wire is 20 850 lb. per sq. in. The largest bending strain at the same time is 5 340 lb. This gives a total

PLATE CXI.
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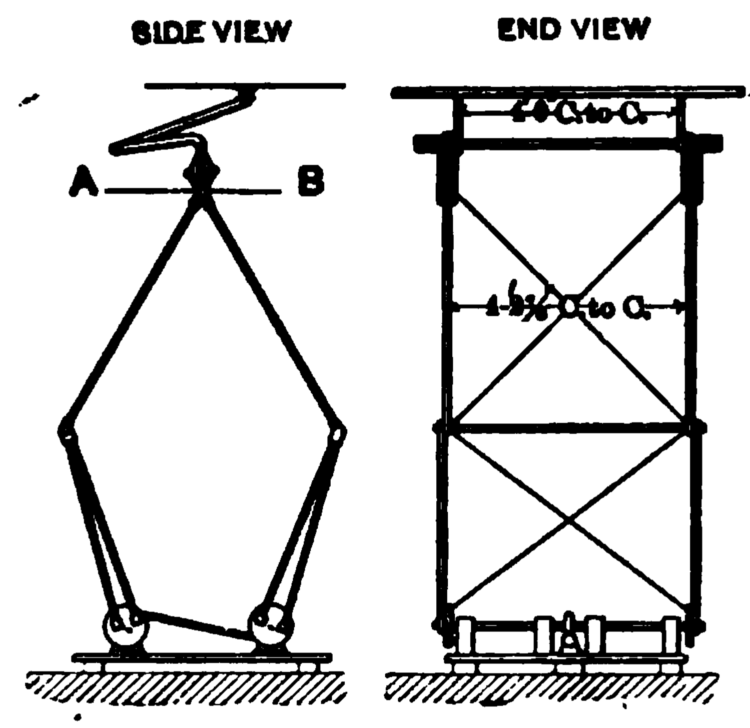
DECEMBER, 1907.
MAYER ON
SUSPENSION FOR WIRES OF ELECTRIC RAILWAYS.

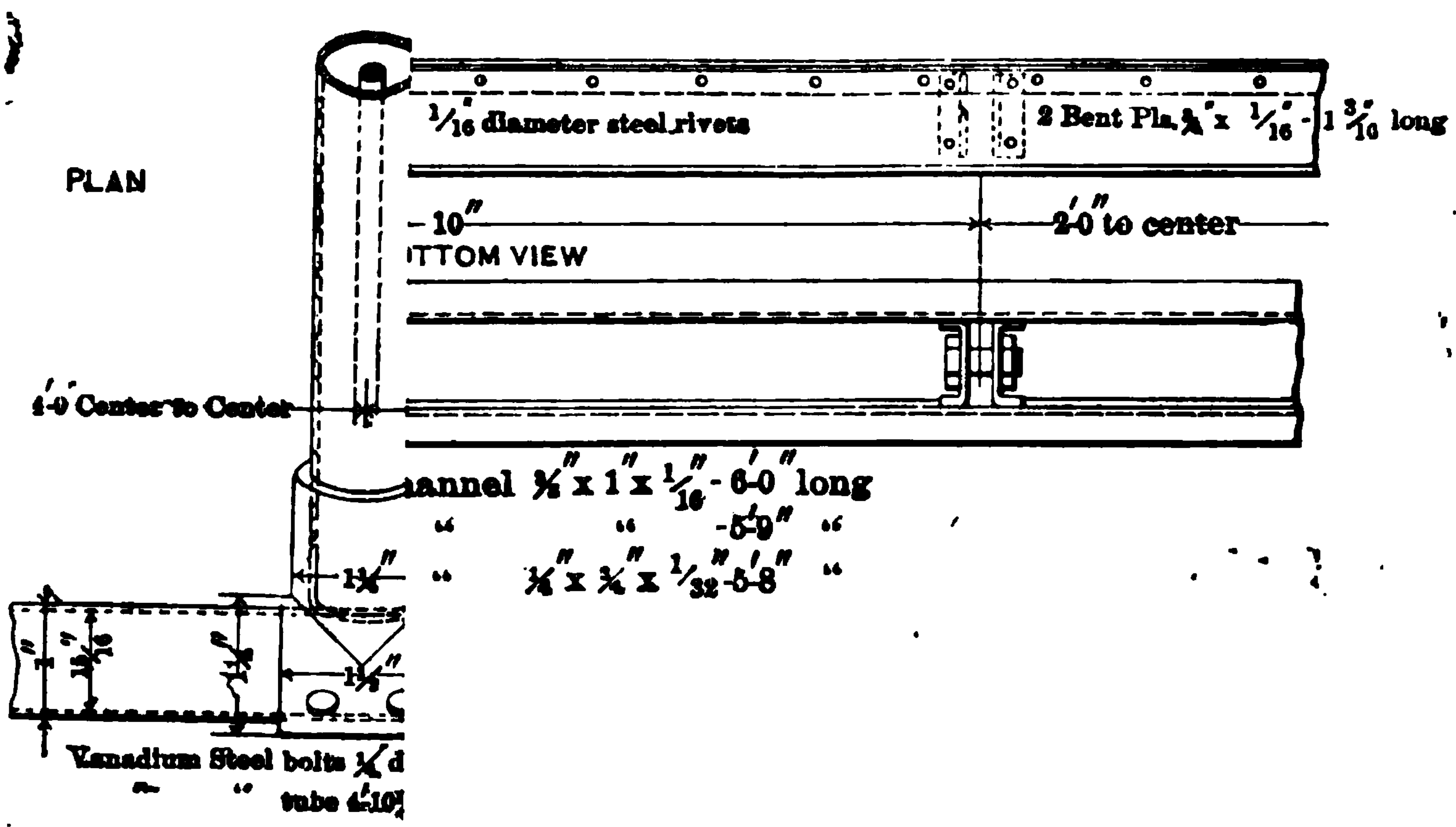


HIGH-SPEED SLIDING BOW
VERTICAL RANGE OF MOTION 8 FT.
PART ABOVE A-B IS NEW
SCALES

Extreme posi
Bow Pin 14.7
Range of Ver
relative to hi

This Bow is suitabl
speeds up to 50 mile
and for 75 miles per
Equivalent Weight

M SLIDING BOW



maximum strain 26 190 lb. No ice was assumed on the contact wire. Ice averaging ¼ in. in thickness, increasing the diameter by ½ in., would increase the tension to 22 450 lb. per sq. in.

These strains give to the contact wire about the degree of safety of first-class railroad bridges. They amount to about as much as the maximum tensions, exclusive of bending strains, in the contact wires of the best catenary suspensions of the United States.

For a speed of 80 miles per hour, the equivalent weight of the sliding bow should not exceed 2½ lb., that is, the sliding bow and its frame should produce no larger centrifugal force than a weight of 2½ lb. moving like the contact point. With a wind pressure of 12 lb. per sq. ft. of wire, counting diameter into length as the area, its largest lateral deflection is 1.8 ft.

To avoid cutting a groove in the sliding bow, the suspenders must be placed alternately to the right and left of the center line of the track. The sliding bow must have an effective length of 4 ft.

The suspender is similar in its action to the saddle carrying a cable of a suspension bridge. It is an inverted saddle, open below, and provided with sides and a roof against which the wire rests when it is deflected upward or to the sides. The term, saddle suspension, therefore, appears to be an appropriate name.

The strain adjuster, shown on Plate CXII, consists essentially of two half suspenders, each cast in two pieces, and carrying cross-heads which are guided by a stout steel bar and moved by steel or bronze screws. The half suspenders change the direction of motion of the sliding bow to a horizontal one. Two properly shaped plates form the track for the sliding bow between the two half suspenders. The whole is attached to a suitable frame, and is carried by insulators from a bridge crossing the tracks. The distance between the two half suspenders can be varied about 2 ft. 8 in. by turning the screws. The brackets carrying the other suspenders must be hinged at the posts, so as to permit free motion of the suspenders within a limited range, approximately in the direction of the track, without changing the direction of the suspenders. The tension in the contact wire will then automatically readjust the position of the suspenders and the lengths of the spans when the screws of the strain adjusters are turned. The same end can also be easily attained by span wire construction.

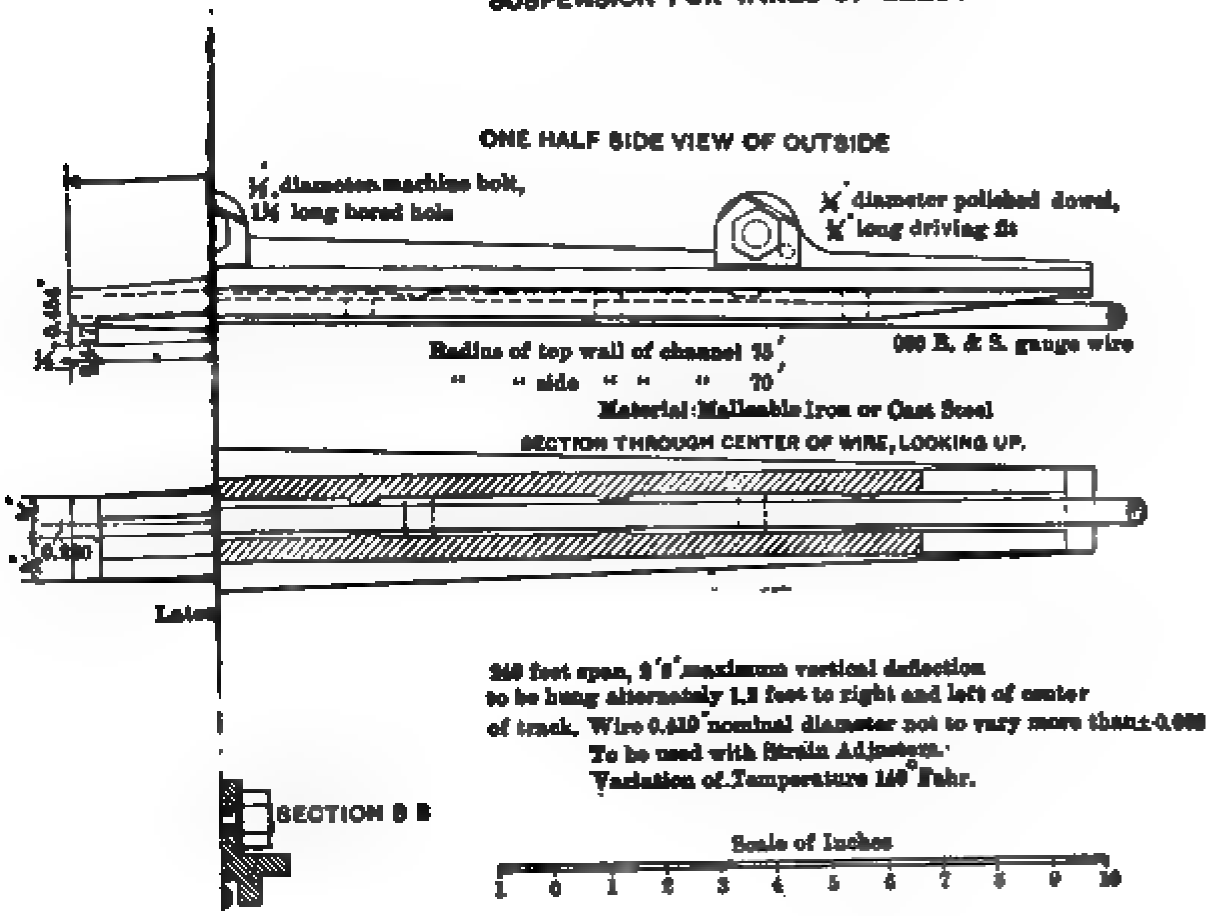
The bridge carrying the strain adjusters and its supporting posts should be of sufficient strength to serve as an anchorage in case the contact wire of an adjoining span is broken by a derailment overturning a post. The swinging brackets or span wires, in this case, will probably prevent the overturning of other posts. The adjustment must take place once or twice in the fall, when the cross-heads are let out, and as often in the spring, when they are pulled together. It will generally be possible to reduce the variation of temperature with one adjustment to 84° fahr. or less. These strain adjusters effect a large reduction of the maximum tension in the contact wire, and thereby make possible the safe use of longer spans with moderate maximum deflections. An automatic adjustment producing constant tension in the contact wire would be desirable, and is attempted in the Blankenese-Ohlsdorf line. It is reported that the contact wire is run over pulleys to the side of the track and attached to counterweights. The wires used are probably grooved, and at least 0.2 in. wide. Running such a wire over a pulley 25 ft. in diameter results in a bending strain of 10 667 lb. per sq. in. This balances the reduction in tension obtained. To gain any advantage, a much larger pulley must be used.

The writer believes that large bending strains in the contact wire cannot be avoided in any adjustment appliance, without using substantially the suspender here described. After a number of futile attempts to find something more perfect and automatic than his strain adjuster, he arrived at the conclusion that a further reduction of the maximum tension in the contact wire cannot be obtained at moderate cost by any sufficiently simple and reliable strain adjuster.

With the catenary constructions, large deflection of the contact wire by the sliding bow must be prevented by the stiffness and tension of the wire. To obtain these safely, a large wire is essential for high speed. With the saddle suspension, 0 B. & S. gauge wire is fully adequate to obtain the requisite mechanical strength, therefore, with it, the size of the wire is mainly governed by the needed electrical conductivity.

On a superficial consideration it would appear that it is more difficult to make a sliding bow that will rise and fall 1 or 2 ft. during the passage of a 240-ft. span than to make one that will rise and fall ½ in. or 1 in. in a span of 10 or 13 ft. The opposite, however, is true.

PLATE CXII.
PAPERS, AM. SOC. C. E.
DECEMBER, 1907.
MAYER ON
SUSPENSION FOR WIRES OF ELECTRIC RAILWAYS.



CTOR

nd 2'-1 long

long

long

Lower edge of two ½" steel plates
horizontal for 2'-9" length

The sliding bows used with catenary suspensions must be able to follow the wire at overhead and grade crossings; therefore, they must have a range of vertical motion of about 8 ft. Unless the approach slopes to these crossings are made very long, the sliding bows must be able to follow the contact wire around a considerable vertical angle.

With the saddle suspension, the sliding bow must follow a vertical angle in the contact line at every suspender. The necessary ability to do so is used more often with the saddle suspension. The sliding bow described in Appendix C can be used for the highest railway speeds with a properly designed saddle suspension.

The sliding bow for the catenary suspension must also be fit for extremely rapid oscillations of small amplitude. In oscillations of the same amplitude, the maximum velocity of the oscillating body is proportional to the number of oscillations per second, and the maximum acceleration is proportional to the square of this number. The maximum velocity and acceleration are both proportional to the amplitude. The variation of the contact pressure is proportional to the maximum vertical acceleration of the sliding bow. With the same law of oscillation, the same maximum acceleration would be obtained if the amplitude were inversely proportional to the square of the number of oscillations per second. In this case the amplitude of the large and slow oscillations with the saddle suspension and that of the small and rapid oscillations with the catenary suspensions are about inversely proportional to their numbers per second. The laws of the two oscillations are not the same, but it is evident that, with the suspenders here described, the small and rapid oscillations of the catenary suspensions require a larger upward acceleration of the sliding bow, and therefore produce a larger reduction of the contact pressure.

With the catenary suspensions, the calculation of the variation of the contact pressure is extremely complicated, and, the writer believes, has never been accurately performed. With a properly designed saddle suspension, the calculation is simple, the shortest radii of the curvature of the motion of the sliding bow being given in the design of the suspender.

The foregoing gives the results of the writer's investigations, the proofs are given in the appendices.

Reviewing the problem: The aim is a safe contact wire, cheap to

construct and maintain, offering a suitable track for a rapidly moving sliding bow. The wire is safe if exposed to moderate maximum strains not exceeding three-fourths of its elastic limit. To prove its safety, the bending strains and tensions produced by the incident forces and the changes of temperature must be calculated.

Appendix A gives the derivation of approximate formulas for calculating the bending strains produced by normal forces in a wire under tension.

Appendix B calculates the maximum coexisting bending strains and tensions for a particular case of the saddle suspension; it also gives the bending strains and tensions for a suspension with ordinary clamps.

Appendix C gives the theory and description of a sliding bow, suitable, with the highest train speeds, for the saddle suspension. In previous pamphlets, entitled: "Overhead Contact Lines" and "The Saddle Suspension," the writer has described the same problem, and has there compared the different suspensions. His views on several details have since been modified by a study of the action of sliding bows.

APPENDIX A.

In many designs of suspensions, the bending strains in the contact wire far exceed the tensions. Their neglect makes many inferences from calculations of the tension only utterly misleading.

The writer has developed formulas for calculating the bending strains in the contact wire produced by a known pressure of the sliding bow, and those at the ends of the clamps firmly holding the wire in a fixed direction produced by lateral and vertical deflections. For round copper wires having a modulus of elasticity of 16 000 000 lb. per sq. in. the formulas are as follows:

For 0000 B. & S. gauge wire $S = 10\,900 \dfrac{Q}{\sqrt{T}}$

" 000 " " " " $S = 11\,800 \dfrac{Q}{\sqrt{T}}$

" 00 " " " " $S = 12\,700 \dfrac{Q}{\sqrt{T}}$

" 0 " " " " $S = 13\,600 \dfrac{Q}{\sqrt{T}}$

Q is the pressure of the sliding bow, in pounds;
T is the tension in the wire, in pounds;
S is the bending strain per square inch.

The formulas are approximately correct for the usual values of Q and T.

In a wire held in a clamp and exposed to a tension, T, differing in direction from that of the wire where it issues from the clamp there arises a bending strain largest at the end of the clamp. If the tension, T, is decomposed into a component acting in the direction of the issuing wire and a component, N, normal to it, then the above formulas give the bending strain per square inch for $Q = 2\,N$.

The proof for these formulas for wires with a modulus of 20 000 000 lb. per sq. in. is given in the writer's pamphlet, "Overhead Contact Lines," S is approximately proportional to the square root of the modulus of elasticity.

APPENDIX B.

Calculation of a suspender for a 240-ft. span of 000 wire with 2 ft. 6 in. maximum vertical deflection for a train speed of 80 miles per hour. Variation of temperature 140° fahr., reduced in effect to 84° fahr. by strain adjusters.

By numerous trial calculations, it was found that, with the assumed speed, the design of a suitable sliding bow is difficult with larger deflections. Longer spans give maximum strains in the contact wire which, though much smaller than those in the contact wires of most catenary suspensions, are believed to be inadvisable at the start. A large factor of safety is possible with this suspension without excessive cost and complication, therefore, it has been the governing consideration in selecting the design.

With a deflection of 2 ft. 6 in., the vertical terminal slope of the wire is 4.17 per cent. A train running at 80 miles per hour will have generally two sliding bows; these lift the wire and approach the suspender at a much flatter slope. The weight carried by the wire to the suspender is reduced by the two approaching bows by an amount depending on their contact pressure and distance apart. With a contact pressure of 15 lb., which is needed for preventing jumping at the suspenders, and 30 ft. distance of the two sliding bows, the weight carried by the wire to the suspender is decreased, at the arrival of the first bow, from 60.8 lb., the weight of a half span of wire, to 32.7 lb. The slope of approach of the sliding bow is reduced in the same ratio, or to $4.17 \times \frac{32.7}{60.8} = 2.24$ per cent. The vertical component of the velocity of the sliding bow at 80 miles per hour is then $117.33 \times 0.0224 = 2.63$ ft. If there is occasionally only one sliding bow, this upward velocity of approach to the suspender is:

$$4.17\% \times \frac{45.8}{60.8} \times 117.33 = 3.14\% \times 117.33 = 3.678 \text{ ft.}$$

As shown in Appendix C, this can be easily taken care of by the sliding bow there described.

The length of one span of the contact wire is given by the formula:

$$S = L + \frac{8}{3}\frac{D^2}{L} = 240 + \frac{8 \times 2.50^2}{3 \times 240} = 240.0694 \text{ ft.}$$

The tension due to the weight of the wire is:

$$T = \frac{0.507 \times 240^2}{8 \times 2.5} = 1\,460.2 \text{ lb.}$$

The stretch produced by this tension is:

$$\frac{1\,460.2 \times 240}{0.1317 \times 16\,000\,000} = 0.1663 \text{ ft.}$$

The length of the wire without tension, therefore, is 239.9031 ft. The tension in the wire at maximum temperature with a wind pressure of 12 lb. per sq. ft. is:

$$\frac{0.652 \times 240^2}{8\ \delta} = \frac{4\,694.4}{\delta},$$

where δ is the deflection. The stretch by this tension is $\frac{0.5347}{\delta}$ ft. Equating the length with the deflection, δ, to the length without tension plus the stretch, we obtain:

$$\delta^3 + 8.721\ \delta = 48.12.$$

And from this, $\delta = 2.854$ ft.: This gives a tension, with maximum temperature and wind pressure, of 1 645 lb., or 12 490 lb. per sq. in. The greatest lateral deflection is:

$$2.854 \times \frac{0.410}{0.652} = 1.8 \text{ ft.}$$

By a similar equation, the deflection at minimum temperature with a wind pressure of 6 lb. per sq. ft. is found to be 1.434 ft., and the tension 2 746.5 lb., or 20 850 lb. per sq. in. With ice on the wire, ½ in. thick, and a wind pressure of 6 lb. per sq. ft. on the enlarged wire, the deflection is 2.06 ft., and the tension 2 956 lb., or 22 450 lb. per sq. in. The least vertical deflection occurs at minimum temperature with wind and without ice; it is 1.33 ft. This gives, for the least vertical terminal slope of the wire, 2.66 : 120 = 2.22 per cent.

The maximum vertical terminal slope was found to be 4.17 per cent. To allow for the possible inaccuracy in the erection, and in the modulus of elasticity of the wire, and for small changes of grade, the writer will assume a variation of ± 0.24% from the calculated minimum and maximum terminal slopes. This makes the new maximum slope 4.41 per cent. If the tube is made to slope 3%, then the wire hangs down 1.41% below it. This results in a bending strain. The tension with maximum vertical slope is 1 460 lb. The component normal to the tube is:

$$0.0141 \times 1\,460 = 20.65 \text{ lb.}$$

In Appendix A it is shown that the corresponding bending strain in the wire is:

$$\frac{23\,600 \times 20.65}{\sqrt{1\,460}} = 12\,730 \text{ lb. per sq. in.}$$

This occurs together with a tension of 11 088 lb., giving a total strain of 23 818 lb. per sq. in.

As the tension increases, by the reduction of the vertical deflection, this bending strain rapidly decreases. The largest lateral deflection was found to be 1.8 ft.; this corresponds to a terminal lateral slope of 3 per cent. If the radius of the side walls of the terminal channels

is made 70 ft. and their length 14 in., then the terminal tangent to the side wall has a lateral slope of 14 : 840 = 1.67 per cent. If the wire rests against the side wall, it leaves the suspender with this lateral slope. The difference between this and 3% is 1.33%, and produces a bending strain in the wire. The tension at the same time is 1 645 lb., or 12 490 lb. per sq. in. The normal force acting on the wire is 1 645 × 0.0133 = 22 lb. The corresponding bending strain is:

$$\frac{22 \times 23\,600}{\sqrt{1\,645}} = 12\,800 \text{ lb.}$$

This would produce a lateral curvature with a radius of 21 ft. 4 in.

The sliding bow, at the same time, may produce a bending strain of:

$$\frac{15 \times 11\,800}{\sqrt{1\,645}} = 4\,365 \text{ lb.}$$

The resultant of the two bending strains is:

$$\sqrt{12\,800^2 + 4\,365^2} = 13\,530 \text{ lb. per sq. in.}$$

This, together with the tension, gives a total of 26 330 lb. The actual bending strain is much less than the amount here calculated because the wire, being bent at the end of the side wall to a shorter radius than that of the side wall, lifts off it and issues from the suspender with a larger lateral slope than assumed. This greatly reduces the lateral bending strain and leaves a safe margin for error in erection.

The least vertical end slope of the contact wire when not affected by sliding bows was found to be 2.22%, or, allowing for 0.24% error from various sources, 1.98 per cent. This is reduced by the raising of the wire by two approaching sliding bows. A sliding bow with a contact pressure, Q, at the distance, A, from the end of a span, L, diminishes the weight carried by the wire to that end by $\frac{L - A}{L}\,Q$. If Q is 15 lb., and there are two sliding bows 30 ft. apart, one at the suspender, then the weight carried by the wire to the suspender is decreased by 28.12 lb. The tension in the wire with minimum slope is 2 746 lb. The terminal slope, therefore, is reduced 1.02 per cent.

This reduction is at one end of the suspender only. The suspender is hung from a horizontal bolt, and can swing freely around it. It will rise toward the approaching sliding bows, reducing the relative change of slope due to this cause to one-half, or 0.51 per cent.

The proper minimum slope for the calculation, therefore, is 1.47 per cent. The difference between this and the tube slope is 1.53 per cent. To produce this difference of slope by a curved top wall of 900 in. radius requires a length of 900 × 0.0153 = 13.77 in. Therefore, 14 in. is ample, with a freely swinging suspender. The 18 in. adopted is adequate for a fixed suspender.

The suspender will turn with every passing sliding bow; therefore, it is very improbable that it will get stuck by rust if it has at the start adequate play at the hinge.

The wind pressure and the lateral displacement of the suspenders, however, produce a lateral force which is a source of considerable friction at the hinge. Reasonable doubt about the freedom of motion, therefore, may be entertained, and the safest course, before experience, is to assume the suspender fixed and to make the terminal channels 18 in. long.

Provision might be made for lubricating the hinge, and then it would be safe to reduce the length of the suspender or to increase the radius of the top wall. The latter change would permit the use of a heavier sliding bow without resultant sparking.

For determining the maximum strain in the contact wire, it is necessary to know the bending strains that occur at the same time with the maximum tension. In this case, the wire rests against the top and side walls, and there are no bending strains, outside of the suspender, except from the pressure of the sliding bow.

In the terminal channels, the bending strains are due to lateral and vertical bending with known radii. The strain due to lateral bending is:

$$\frac{0.205 \times 16\,000\,000}{840} = 3\,905 \text{ lb.}$$

That due to vertical bending is:

$$\frac{0.205 \times 16\,000\,000}{900} = 3\,644 \text{ lb.}$$

The combined bending strain is:

$$\sqrt{3\,644^2 + 3\,905^2} = 5\,340 \text{ lb.}$$

If the terminal channels were omitted, the bending strain due to wind pressure would be 30 300 lb. The vertical bending strain would be about one-half as much, and the resultant of the two, 34 000 lb. per sq. in. This, with 12 800 lb. tension, would give a maximum strain of 46 800 lb. The suspension would be unsafe, even with the 84° variation of temperature here assumed. Without strain adjusters, the tensions, or the bending strains, or both, would be vastly increased. At high speeds, the suspender would receive a severe blow and the wire a violent jerk with every passing sliding bow. Most sliding bows would be broken.

It is of interest, in obtaining a practical confirmation of this theory, to calculate the strains in the contact wire of an ordinary trolley wire suspension for a span of 100 ft. of 000 B. & S. gauge, round wire, for variations of temperature of 140° fahr., with a wind pressure of 12 lb. per sq. ft. in summer, and 6 lb. per sq. ft. in winter.

Trial calculations show that a maximum deflection of about 1½ ft.

gives the smallest maximum strain in the wire. A down slope of 1½% where the wire leaves the clamp is most favorable.

The strain, with maximum temperature and wind pressure, is 4 000 lb. tension and 27 750 lb. bending, giving a total strain of 31 750 lb. per sq. in. At minimum temperature, with wind, and with two sliding bows of 15 lb. contact pressure 30 ft. apart, the tension is 15 600 lb. and the bending strain 16 900 lb., giving a total strain of 32 500 lb. per sq. in. The terminal down slope of the wire, at maximum temperature, without wind, is 6%; at high speed, this, though reduced by the approaching sliding bow, when without adequate transition curve, is dangerous to the wire, the clamp, and the sliding bow. The suspension, therefore, is only suitable for moderate speeds. The above maximum strains are only moderately safe. These results agree with actual experience. With smaller wires, the lateral deflections and the strains are larger, and the degree of safety is reduced.

The saddle suspension for 240-ft. spans, here proposed, gives much smaller maximum strains in the contact wire, and, for all deflections, provides transition curves of large radius which make high speeds harmless.

APPENDIX C.

SLIDING BOWS FOR HIGH-SPEED ELECTRIC RAILWAYS.

The contact wire which forms the track for the sliding bow is suspended either at short or long intervals. In the former case, the weight of a half span of contact wire is generally much less than the upward pressure of the sliding bow, called the contact pressure. The wire, therefore, is bent up by the bow beyond the supports. In the latter case, the wire of a half span weighs more than the amount of the contact pressure; it is lifted by the bow from its normal sag to a position still below the horizontal. In all cases, the bow moves along vertical curves. At high speeds this produces a considerable amount of centrifugal force, which, according to its up or down direction, increases or reduces the contact pressure. The increase should not be so large as to produce dangerous bending strains in the wire; the reduction should not be so large as to cause separation of the bow from the wire and consequent sparking. The centrifugal force is proportional to the weights of the parts of the bow and of its supporting frame which move in curves, and to the square of their speed, and inversely proportional to the radii of curvature of their motion. It is given by the equation:

$$C = \Sigma \frac{w\,v^2}{g\,R} = \frac{v^2}{g} \Sigma \frac{w}{R}$$

where C is the centrifugal force, in pounds, v is the train velocity, in feet per second, g is 32.2 ft., $\frac{w}{R}$ is the weight of a part of the sliding bow or of its frame divided by the radius of its motion.

$\Sigma \frac{w}{R}$ is the sum of all these quotients for the sliding bow and its frame. If $\Sigma \frac{w}{R} = \frac{W}{r}$, where r is the radius of curvature of the motion of the contact point, then W is the equivalent weight of the sliding bow and its frame; it is the weight which, if moving as the contact point, produces the same centrifugal force as the sliding bow and its frame. With the saddle suspension, r, at the center of the suspender, is conveniently made from 5 to 12 ft. Here the sliding bow presses against the suspender, and a large contact pressure will not endanger the wire. In the terminal channels of the suspenders the wire is generally convex downward, and the centrifugal force reduces the contact pressure. r can here be made 75 ft. with, and 40 ft. or more without, strain adjusters. For a speed of 80 miles per hour, an equivalent weight, W, of 2.5 lb. and a radius, r, of 75 ft., the centrifugal force is $C = \frac{2.5 \times 117.33^2}{32.2 \times 75} = 14.25$ lb. A minimum

static contact pressure of 15 lb. will be reduced by the centrifugal force to 0.75 lb., and will be adequate to prevent interruption of contact at the suspenders.

For a speed of 50 miles per hour, an equivalent weight, W, of 3 lb. and a radius, r, of 40 ft., the centrifugal force is $C = \frac{3 \times 73.33^2}{32.2 \times 40} = 12.52$ lb. A static contact pressure of 15 lb., therefore, is ample to prevent interruption of contact at the suspenders.

Plate CXI shows a sliding bow of 3 lb. equivalent weight when 6 ft. long with 8 ft. range of vertical motion. The bow is made of three aluminum channels, and is 6 ft. long, over all. It has a shallow space for grease which latter must be sticky so as not to be thrown out by centrifugal force. The bow proper is connected by hinges to two radial arms. The latter are bolted to a tubular shaft. The shaft rests in bearings carried by the ends of two bent tubes. Each of the bent tubes is held by a pin and a sleeve. The sleeve forms the upper hinge of the main diamond frame. This diamond frame has extensions upward giving support to the top of the tubes. The shaft carrying the radial arms also carries at each end two springs. The free ends of the larger or main springs are inserted into holes in the hubs of the bent tubes. The free ends of the smaller springs rest against the lower sides of these hubs. The main springs press the radial arms up; the smaller reverse springs press them down.

The frame below A-B can be designed so that its upward pressure, when it rises with uniform speed, is approximately constant and produces a contact pressure of 15 lb. for sliding bows intended for maximum speeds of 50 miles an hour. The contact pressure required to make the frame fall with uniform speed is 15 lb. plus twice the friction. Assuming the friction at 2 lb., the contact pressure with uniformly falling frame is 19 lb.

In the following 15 lb. is called the active or minimum static contact pressure, and 19 lb. the passive or maximum static contact pressure. The equivalent weight of an ordinary diamond-frame sliding bow can be greatly reduced by using an aluminum bow and light vanadium steel tubing with McAdamite connection castings. It will hardly be possible, however, to make it less than 6 lb. for a bow with 8 ft. range of vertical motion. This, as above shown, is too much for the highest speeds.

With the writer's modified frame, the two radial arms carrying the bow are ordinarily in an intermediate position, produced by proper adjustment of the springs. When the bow approaches the suspender of the saddle suspension it rises, together with the frame, the contact pressure being 15 lb. After the bow passes the suspender, the frame continues to rise; the bow itself, which rose as it approached the suspender, is made to fall as it passes the central part of the

latter. The contact pressure at the central part of the suspender is between the latter and the bow, and, at high speeds, exceeds 100 lb. Beginning at the suspender, the radial arms turn down, and the torque of the springs increases. This increasing torque of the springs determines the amount of the contact pressure. Due to the presence of these springs, the contact pressure depends on their rigidity and the direction of the radial arms. The heavy frame below the springs, by its inertia, continues to move up, but with a retarded motion, because the increasing contact pressure (together with the weights) is larger than the constant force pushing it up. After the upward velocity of the frame is reduced to 0 (which occurs, as will be shown, about 0.15 sec. after passing the bow), it begins to move down with an accelerated motion. The radial arms, which have been turning down, begin shortly after to turn up again, and they reach not only their original angle of slope, but rise beyond it. The contact pressure decreases to less than the minimum static pressure, and the downward motion of the frame is retarded; it soon stops, and begins to go up again. After a few oscillations, the damping action of the friction stops the swinging of the radial arms.

It is evident, from the foregoing, that the sliding bow and the radial arms alone follow closely the sharp curves in the motion of the contact point. The sliding bow follows the curves accurately, the parts of the radial arms nearer the shaft move in a different manner and their weight is less important than that of the bow.

The writer, in his paper entitled "Overhead Contact Lines," has shown that the radial arms are equivalent to a weight one-third as large moving like the sliding bow. The sliding bow proper weighs 1.72 lb. The equivalent weight of the sliding bow and radial arms is 3 lb. In this design the two radial arms are bolted to the shaft, they therefore always move through the same angle. The whole sliding bow moves like the contact point. The equivalent weight of the frame largely determines, as will appear from the following calculations, the needed range of relative vertical motion of bow and shaft. The radial arms sometimes point in the direction of the train motion, sometimes backward.

There may be a strong head wind. The wind pressure on the sliding bow is then due to the sum of the velocities of wind and train. If the radial arms point forward, this wind pressure increases the upward slope until it is balanced by the change in the torque of the springs. The amount of the contact pressure is not directly affected thereby. If the radial arms point backward, the wind pressure reduces their upward slope until it is balanced by the changed torque of the springs. In the former case the remaining available upward range, in the latter the downward range, of motion is reduced. It is desirable, therefore, to limit as much as possible the change in the slope

of the radial arms produced by wind pressure. As will appear from the following calculations, this is attained by the use of reverse springs. The action of the reverse springs is limited to only the upper part of the range of motion of the radial arms.

The reverse springs used in the design here described have the same stiffness as the main springs. The change in torque for a given arc of motion, therefore, is twice as much within the range of their action as outside of it.

For showing the range of adaptation of the sliding bow, the writer will assume an unfavorable case, namely: A span of 220 ft., a maximum vertical deflection of 4 ft., a 000 B. & S. gauge wire, and a train speed of 50, with an occasional head wind of 80, miles an hour.

The radial arms are 30 in. long from center of bow hinge to center of shaft. The springs are adjusted so that the bow hinges, which are on the center line of the sliding bow, are 11 in. above the center line of the shaft when the contact pressure is 15 lb., and the train is moving at a speed of 50 miles an hour, while there is no wind, and the radial arms are pointing backward. In this case the wind pressure on the bow and the radial arms is due to the train velocity only; it is equivalent to 3.38 lb. acting on the bow. The weight of bow and radial arms is equivalent to 2.75 lb. at the bow and 1.85 lb. at the shaft. The horizontal distance between the bow hinges and the shaft is:

$$\sqrt{30^2 - 11^2} = 27.91 \text{ in.}$$

The resultant torque of the main and reverse springs must be equal and opposite to the bending moment of the contact pressure, the weight and the wind pressure on the bow and arms, or:

$$(15 + 2.75) \times 27.91 + 3.38 \times 11 = 532.7 \text{ in-lb.}$$

When the radial arms are lowered, the torque of the main springs (pushing them up) increases, that of the reverse springs (pushing them down) decreases. The contact pressure, which is the main force balancing the torque, therefore increases with the lowering of the arms. To avoid interference of the contact wire and the main springs, the bow pins must be at least 3 in. above the center of the shaft. The downward range of motion from the above position, therefore, is 8 in. It has been found by trial that this range is adequate if the contact pressure increases 30 lb. while the bow moves through the whole of it.

To prove the adequacy of this range the writer will choose the springs so that the contact pressure does increase 30 lb. while the bow turns down to 3 in. above the center of the shaft, and will then calculate the actual relative motion of the bow and shaft when the bow advances from the suspender toward the other end of a span, and will thereby prove that the bow does not move beyond the available range.

In the lowest position of the bow, its horizontal distance from the shaft is $\sqrt{30^2 - 3^2} = 29.85$ in. The torque of the springs must balance the moment of the weight, the contact pressure, and the wind pressure around the shaft; or,

$$\text{torque} = (45 + 2.75)\ 29.85 + 3.38 \times 3 = 1\,435.5.$$

The increase in the torque of the springs during this motion, therefore, is:

$$1\,435.5 - 532.7 = 902.8 \text{ in-lb.}$$

The angle, a, of the radial arms (from shaft to hinges) with the horizontal, is given by $\sin. a = \frac{3}{30}$, or $a = 5°\ 44.36'$. The angle, b, for the first position, is given by $\sin. b = \frac{11}{30}$, or $b = 21°\ 31.63'$, and $b - a = 15°\ 47.27'$. The length of the corresponding arc described by the bow is 8.266 in. The reverse springs will be adjusted so that they act through only the first quarter of this arc and are equally stiff with the main springs. The change in torque through the first quarter of the motion, therefore, is twice as much as in any succeeding quarter. The total change in torque, therefore, is as much as in five-fourths of an arc of 8.266 in. with only one spring, or in 10.332 in.

The change in torque per inch of arc is 902.8 : 10.332 = 87.38 in-lb. This applies to the last three-quarters of the motion. During the first quarter the change in torque per inch of arc is 174.76 in-lb. From this the size and length of the springs will be determined, in the following.

The lowest position of the sliding bow will evidently be reached when the radial arms are pointing backward and are turned down by a strong head wind. Assuming the wind velocity 80 and the train velocity 50, their relative velocity is 130 miles an hour. This gives a wind pressure of 45.6 lb. per sq. ft., or, on the sliding bow, 22.8 lb., its area, together with the mean equivalent area of the radial arms, being ½ sq. ft. By trial equations between torques and moments, it is found that the radial arms are lowered 1.05 in. below the position corresponding to 15 lb. contact pressure without head wind. With this head wind, the bow, when it passes the suspender, is only 9.95 in. above the shaft. Its downward range of motion relative to the shaft, therefore, is only 6.95 in. When the bow is 9.95 in. above the shaft, the angle of the radial arms with the horizontal is 19° 22.2′. The available range of downward motion, measured in degrees, is 19° 22.2′ — 5° 44.36′ = 13° 37.84′. The corresponding arc of the bow measures 7.137 in. Of this arc, 0.937 in. is under both springs with double torque, the remainder, or 6.2 in., under the main spring only. The contact pressure of 15 lb. exists now when the bow is only 9.95 in. above the shaft. The contact pressure in the lowest position is found

from the equation between the torque and the moment of the acting forces. The equation is:

$$(2.75 + X)\ 29.85 + 22.8 \times 3 = 1\,435.5$$

where X is the contact pressure. From this, $X = 43.03$ lb. The increase in contact pressure during the down motion of 6.95 in., therefore, is $43.03 - 15 = 28.03$ lb. Of this motion, 0.89 in. is under the reverse springs, and 6.06 in. under the main springs only. Counting the first part double, we have 7.84 in. Dividing 28.03 by 7.84 we obtain, where only the main springs act, 3.58 lb. as the change in the contact pressure per inch of vertical relative motion of bow and shaft, and, where the reverse springs also act, twice as much, or 7.16 lb.

The actual relative motion of bow and shaft, after the bow passes a suspender, will now be calculated. Before the bow reached the suspender, it and the shaft were moving up together along the contact wire. It is necessary to ascertain the upward velocity of the shaft at the moment when the suspender is passed. The most unfavorable case is that with maximum deflection of the contact wire. For this case the deflection is 4 ft. and the span is 220 ft. The terminal down slope of the contact wire, therefore, is $\frac{8}{110} = 7.273$ per cent. The weight of a half span of the wire is 55.8 lb. This terminal slope is reduced by the presence of a sliding bow in the span. This sliding bow lifts the wire. The suspenders are carried either by brackets or a span wire construction between pairs of poles. Their resistance to a small longitudinal motion of the suspenders is small. The tension in the contact wire, therefore, will be but little reduced by the presence of a sliding bow in a span. It will be assumed, for the present, to be constant. The contact wire carries 55.8 lb. to the suspender; when a sliding bow with a contact pressure of 15 lb. approaches, this end shear or vertical component of the tension in the wire is reduced to $55.8 - 15 = 40.8$ lb. The end slope of the wire is reduced to $\frac{40.5}{55.8} \times 0.07273 = 0.05318$. The train velocity is 73.33 ft. The velocity of upward motion of the shaft at the suspender, therefore, is $0.05318 \times 73.33 = 3.896$. The sliding bow and the radial arms are turned down by the suspender; the contact pressure increases; the upward motion of the shaft, therefore, becomes a retarded motion. The different parts of the frame have a different upward velocity and the retardation produced in them is also different. The inertia of the whole frame (exclusive of bow and radial tubes, but inclusive of their hubs) was calculated from a design and found to be equal to that of a weight of 16.1 lb. moving with the vertical velocity of the shaft carrying the radial arms. This estimate is based on the use of nickel or vanadium steel tubing of not more than the thickness needed for

ample strength. A vertical force of 1 lb., acting on the frame, therefore, will produce an acceleration of the shaft of 2 ft. per sec.

Considering now what happens after the sliding bow passes the suspender, it is evident that the bow and the radial arms are turned down by the suspender and move along the wire, which latter is raised by the contact pressure. The frame and the shaft continue to rise by their inertia. The initial upward velocity of the shaft is 3.896 ft. Taking an interval of $\frac{1}{40}$ sec., the contact pressure at the start is 15 lb.; it increases during this time by an amount depending on the relative motion of shaft and bow. The retardation of the shaft depends on this increase of the contact pressure. The position of the sliding bow at the end of $\frac{1}{40}$ sec. depends on the contact pressure then existing. A formula might be developed for finding the relative vertical motion of shaft and bow, but a more convenient and shorter method is to assume the relative motion, to find the corresponding contact pressure at the end of the time interval, and to calculate from it the consequent motion of shaft and bow and their relative motion. If the result does not agree with the assumption made, another relative motion must be assumed, and the calculation repeated. After two calculations the proper value can generally be found closely by interpolation. This, though circuitous, is believed to be shorter than the development of formulas for the many different cases which must be considered. Assuming, then, the relative motion of shaft and bow during the first $\frac{1}{40}$ sec. to be 2 in., the contact pressure during the first 0.89 in. of this relative motion increases 7.16 lb. per in.; after this it increases 3.58 lb. per in.; at the start it is 15 lb. At the end of the time interval it is $[15 + (3.58 \times 0.89)] + (3.58 \times 2) = (18.19 + 7.16) = 25.35$ lb. The average contact pressure during the interval is $\frac{15 + 25.35}{2} = 20.175$ lb. This is 5.175 lb. in excess of the 15 lb. which would allow uniform upward motion of the frame. The average retardation of the motion of the shaft produced thereby is 10.35 ft. The consequent reduction of velocity during $\frac{1}{40}$ sec. is 0.259 ft. The end velocity of the shaft is $3.896 - 0.259 = 3.637$ ft. The average velocity during this interval is $3.896 - 0.130 = 3.766$ ft. The upward motion of the shaft, in inches, is $\frac{3.766 \times 12}{40} = 1.130$ in. The contact pressure at the end of the interval is 25.35 lb. The sliding bow has advanced from the center of the suspender by $\frac{73.33}{40} =$ 1.8333 ft. To obtain a convenient formula for finding the position of the sliding bow, with a contact pressure, P, after n intervals of $\frac{1}{40}$ sec., the distance of the sliding bow from the near end of the span is $n \times 1.8333$ ft. Of the pressure, P, there goes to the near end of the

span, $P\frac{(220 - 1.8333\,n)}{220}$. The weight of the assumed wire is 0.507 lb. per ft. One-half the span (or 0.507×110) is carried to each end. The load carried to the near end of the span is $0.507 \times 110 - P$ $\frac{P \times 1.8333\,n}{220}$.

This is the shear at the end of the span, or the vertical component of the tension in the wire. The wire between the sliding bow and the near end of the span hangs in a curve. The chord of this curve is parallel to the tangent in its center. The direction of this tangent depends on the shear at this point and the tension in the wire. This shear is equal to the end shear less $\frac{n \times 1.8333 \times 0.507}{2}$. Subtracting this from the end shear and reducing the result to convenient form, we obtain $(55.8 - P)\left(1 - \frac{1.8333\,n}{220}\right)$ lb. The down slope of this tangent is less than the terminal slope of 0.07273 in the ratio of this shear to the shear of 55.8 lb. Therefore, it is

$$\frac{(55.8 - P)\left(1 - \frac{1.8333\,n}{220}\right)}{55.8} \times 0.07273.$$

The drop from the suspender to the contact point is equal to the slope multiplied by the distance, or, after reduction and expression in inches, $(55.8 - P)\,(1 - 0.008333\,n)\,0.0287\,n$. From this formula we get the drop of the bow after $\frac{1}{40}$ sec. for the assumed relative motion of shaft and bow of 2 in. by making $P = 25.35$ and $n = 1$. This gives for the drop of the bow 0.867 in. We found that the shaft rises 1.130 in. in the same time interval. This gives 1.997 in. for the relative motion of bow and shaft in the first $\frac{1}{40}$ sec. This is so close to the assumed 2 in. that no further trials are necessary.

For the second $\frac{1}{40}$ sec. the relative motion of shaft and bow is assumed to be 1.5 in. For the relative motion during $\frac{1}{20}$ sec., this gives $1.997 + 1.5 = 3.497$ in. The contact pressure at the end of this interval is $18.19 + (3.497 \times 3.58) = 30.72$ lb. The average contact pressure during the second $\frac{1}{40}$ sec. is 28.04 lb. This is 13.04 lb. in excess of the pressure which would allow a uniform rise of the shaft. This produces an average retardation of 26.08 ft., and a reduction of velocity in the interval of 0.652 ft. The velocity at the end of the previous interval was 3.637 ft. The upward velocity of the shaft at the end of the second $\frac{1}{40}$ sec. is $3.637 - 0.652 = 2.985$ ft. The average velocity during the interval is $3.637 - 0.326 = 3.311$ ft. The consequent upward motion of the shaft is 0.993 in. The previous upward motion of the shaft was 1.130 in. The total upward motion of the shaft during $\frac{1}{20}$ sec., therefore, is 2.123 in. From the above formula

the downward motion of the bow is found by making $P = 30.72$ and $n = 2$. The downward motion of the bow during $\frac{1}{10}$ sec. is 1.416 in. The relative motion of shaft and bow during $\frac{1}{10}$ sec., therefore, is $2.123 + 1.416 = 3.539$ in. A repetition of the calculation with a slightly larger assumption for the relative motion gives approximately:

Motion of shaft in $\frac{1}{10}$ sec....................	2.123 in.
Motion of bow............................	1.407 "
Total relative motion in $\frac{1}{10}$ sec...............	3.530 in.

The calculation, continued in the same manner, shows that the relative motion of shaft and bow reaches its maximum after 0.15 sec., and is then 5.99 in. After this the radial arms begin to move up again and they reach their original slope corresponding to a relative motion 0 after 0.47 sec. The arms rise further until the vertical distance between bow and shaft is 1.626 in. more than at the start. The contact pressure is then only 3.17 lb. This occurs 0.70 sec. after passing the suspender. The arms begin then to move down a second time. After a few swings the oscillation is stopped by the friction. This calculation is not accurate mainly because the tension in the contact wire, which was assumed constant, is slightly reduced by the action of the sliding bow. This reduction, however, is small, partly because the sliding bow during the first oscillation, which is the largest, is near the end of the span, and partly because the suspenders can move easily a fraction of an inch in the direction of the track. The margin for the downward motion is about 1 in.; this will be reduced by the reduction in tension in the contact wire.

It is evident that the amount of the initial upward velocity of the shaft when the bow passes the suspender is a very important factor deciding whether the range of relative vertical motion of bow and shaft allowed is adequate. This initial velocity depends on the terminal slope of the wire, the ratio between static contact pressure and the weight of a half span of wire, and especially on the train velocity.

When the radial arms are turned forward, a head wind of 80 and a train speed of 50 miles an hour cause a rise of the bow. With 15 lb. contact pressure, the bow rises to an elevation of 12.8 in. above the shaft. It will rise approximately 1.9 in. more during the oscillation. There is plenty of upward range of motion to allow this rise.

For obtaining a small equivalent weight for the bow and radial arms, it is important that the radial arms form a small angle with the horizontal. When the bow follows a curve in the contact wire, an approximately vertical acceleration of $\frac{v^2}{r}$ must be given to it by an external force, where v is the train velocity and r is the radius of curvature of the motion of the bow. This acceleration is produced by

the turning of the radial arms. This turning moves the bow normal to the arms. The vertical component of its motion is only equal to the motion multiplied by the cosine of the angle, a, of the radial arms with the horizontal. The acceleration of the bow and of the ends of the radial arms, therefore, must be equal to $\frac{v^2}{r \cos. a}$. The variation, P, of the approximately vertical contact pressure produces this acceleration; this pressure forms an angle, a, with the acceleration, and its component in the direction of the acceleration is $P \cos. a$. The force to produce the acceleration is equal to the mass to be moved multiplied by the acceleration, or

$$P \cos. a = M \frac{v^2}{r \cos. a}, \text{ or } P = M \frac{v^2}{r \cos.^2 a}.$$

M is the mass which if placed at the bow offers the same resistance to turning as the bow and the radial arms. M is approximately equal to the mass of the bow plus one-third of the mass of the arms. It is evident that P, or the variation of contact pressure due to centrifugal force, is greatly increased if the angle, a, is large. To obtain a small variation of contact pressure due to centrifugal force, or, in other words, a small equivalent weight of the sliding bow, the arms should form a small angle with the horizontal. This is the main reason why the reverse springs, which greatly reduce the variation of elevation of the bow above the shaft, are necessary for obtaining a small equivalent weight. The angle of the radial arms with the horizontal when the sliding bow passes the suspender is the only important one in calculating the equivalent weight of the sliding bow. The angle, a, with a head wind of 80, and a train velocity of 50, miles per hour with the radial arms turned forward, and, when the bow passes the suspender, is given by $\sin. a = \frac{12.8}{30} = 0.4267$. This gives $\cos.^2 a = 0.8179$, and $\frac{1}{\cos.^2 a} = 1.223$. The equivalent weight, $M g$, for the bow and radial arms is 2.4 lb. This is increased, due to their slope when at the suspenders, to $2.4 \times 1.223 = 2.94$ lb. Allowing for some inaccuracy, it may be 3 lb.

Referring to the main springs: There is in each main spring a maximum torque of 718 in-lb. Their strength is given by the equation, $718 = \frac{\pi d^3}{32} s$, where d is the diameter and s the strain per square inch. Taking s, for hardened spring steel, $= 100\,000$ lb., then $d = 0.418$ in. The length of the spring is found by the equation, $f = \frac{64 \, P \, l \, r^2}{\pi \, E \, d^4}$. In this equation, r is 30 in., f is the arc through which the bow moves by the application of the force, P, acting along the

tangent with the radius, r. It has been found that, for $f = 1$ in., $P \times r$ must be 87.38 in. This gives for l, the length of the spring, 33.2 in. In the same manner, the reverse spring, shown on Plate CXII, was calculated.

Higher speeds than 50 miles an hour, together with a head wind of 80 miles an hour, are only practicable with trains of cars. Such trains have more than one sliding bow. The wire, therefore, is lifted much more than with one bow. The initial upward velocity of the shaft when the sliding bow passes the suspender is thereby much reduced, and the same available range of downward motion will generally be adequate. On roads having high train speeds, substantial steel poles will mostly be wanted; with such it is always advantageous to use strain adjusters which permit longer spans or smaller deflections of the contact wire. Either of these diminish the vertical velocity of the shaft when the sliding bow passes the suspender, and the assumed range of relative motion of shaft and bow becomes adequate in spite of the higher speed. The higher speed also requires longer radii of vertical curvature of the contact wire, for the purpose of avoiding jumping of the sliding bow. These longer radii become practicable only if strain adjusters are used.

The sliding bow here described is also suitable for the catenary suspension. Though the wire appears to be straight where this suspension is used, it is bent up by the contact pressure, especially if the suspenders are near together. With a heavy sliding bow, and a slack wire at high temperature, the curvature of the motion of the sliding bow is sharp just before a suspender is reached, and the sliding bow jumps at high speed. A light sliding bow will evidently produce less centrifugal force and less variation of contact pressure, and consequently less jumping. It will run smoothly at much higher speeds than a heavy one.

There are inevitably vertical curves and changes of direction of the contact wire at low overhead crossings and tunnel entrances. These changes will cause much less trouble with a light sliding bow. With catenary suspension and short spans between poles, a sliding bow 4 ft. long, with radial arms 2 ft. long, can often be used. Such a sliding bow can be designed for an equivalent weight of 2 lb. Such a bow will run smoothly at very high speeds.

With the more uniform contact pressure of a light bow, a much smaller static contact pressure can be used. The result will be less wear and greater durability of bow and wire. The increase in the first cost of a diamond-frame bow caused by the modification here proposed will be in all cases amply repaid by the reduced cost of construction and maintenance of the contact line.

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PAPERS AND DISCUSSIONS.

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REINFORCED CONCRETE FOUNDATIONS OVER EXCAVATIONS ON PAVED STREETS.*

BY JOHN MCNEAL, M. AM. SOC. C. E.

Constant excavations on the paved streets of Easton, Pa., and numerous depressions formed over previously excavated trenches, have called the writer's attention to the necessity of providing some means for protecting the surface of the street from gradual settlement below the general level of the adjoining paving.

No matter how carefully the back-filling of a trench is done, there is bound to be a settlement of the earth replaced in the trench, and in some cases this settlement has not begun to show for a year or more after the paving has been replaced.

In order to avoid settlement of the surface, the foundation for repaving over all trenches has been reinforced with expanded metal. For a trench not more than 20 in. in width, the writer uses expanded metal, of 3-in. mesh and No. 10 gauge steel, having a cross-sectional area of not less than 0.185 sq. in. per ft. in width.

After the trench is properly back-filled, the old concrete is removed for a distance of at least 1 ft. beyond each side of the trench, and expanded metal is placed over the entire opening. A thickness of 6 in. of concrete, mixed in the proportion of 1 part Portland cement, 3 parts sand, and 5 parts broken stone, is placed over and around the

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expanded metal in such a manner that the metal is embedded in it, 1½ in. above the base and 4½ in. below the surface.

After the concrete is thoroughly rammed to an even surface, the paving material is replaced on this surface to conform with the adjoining paving.

These requirements met with some opposition at first from corporations and local contractors who are constantly digging up the paved streets for new mains and repairs, but now all excavated trenches are repaved with the expanded metal reinforcement.

REINFORCED CONCRETE FOUNDATIONS
OVER
EXCAVATIONS ON PAVED STREETS.

FIG. 1.

The cost of this foundation per linear foot of trench is about 37½ cents more than that of plain concrete.

Assuming the working strength of the steel to be 20 000 lb. per sq. in., and allowing for the shape of the metal, which distributes the load over 20 in. of trench, a wheel load of from 650 to 700 lb. would be supported safely without the aid of the back-filling below the foundation.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

NOTE ON THE IMPROVEMENT OF THE MISSISSIPPI RIVER.*

By W. G. Price, M. Am. Soc. C. E.

During the past twenty-seven years much work has been done on the Mississippi River between Cairo and New Orleans, but comparatively little has been accomplished in the way of permanent improvement, except in the construction of levees.

The revetting of caving banks by a continuous mattress has certainly not proven to be a permanent form of improvement in many places, and whenever such a mattress is located for a long time in a place where it is opposed to the force of the river flow, it must fail. Much of the mattress which has been placed was constructed in such a manner that, if not carried away bodily by the first flood, it would disintegrate and float away stick by stick, owing to the fastenings being of metal, and soon destroyed by corrosion.

To design structures which will not be carried away has been a difficult problem, but such have been built, and, in the light of experience, still better designs can now be made.

Some years ago the writer was engaged in improving the Harbor of New Orleans. This was done by works which formed what were intended to be fixed points in the bank of the river and could not be

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carried away. The writer believed then that this was the proper way to secure a permanent improvement of the whole river. Some of the work at these fixed points was put in with such details of construction that they should have failed before this time; the writer, however, believes that permanent works on this plan can now be constructed which will confine the river so as to prevent it from wandering away from the place where it is desired to hold it, and also greatly improve the navigable depth. These fixed points would have to be located at various distances apart, depending on the degree of curvature of the river, but the number required would not entail a prohibitive expense, provided each one was put in so as to be a permanent work and not require constant repairs, and it is with the view of giving a hint of how to make such work permanent that this paper has been written.

The Mississippi has shown that it has power to destroy and carry away almost everything that Man has constructed to oppose it. By using a little strategy in design, however, the river can be compelled to use its mighty power to dig foundations for permanent improvement works. This can be done, and has been done, by making the form of construction of these works to be fixed points, so that the river cannot disintegrate them, or move them bodily down stream, but must undermine them; it is known that it can, and will, and it is by taking advantage of this undermining power that the point can be made a fixture.

By designing the structure so that only wood and stone, properly bound together, form its permanent parts, the forces acting against it can do nothing but undermine it and sink it in the sand, while more of the same material is piled on top of that which is sinking, and a depth of foundation is soon reached which the river will not cut under. In this way the flowing water will sink a large structure to a depth which will give a permanent foundation, in the same way that a pile is sunk with a jet of water.

The work must be well connected to the levee, and must extend well out on the bed of the river.

When the writer was building the dam from Turnbulls Island across Red River, in Louisiana, he had no fear of the river being able to destroy the work, or cut around it, and he believes now that it was a great mistake to destroy this dam, by dredging a channel through it, after it was more than half completed.

The writer believes that the power of the flowing water in any silt and debris-bearing stream can be utilized and directed, by a properly designed structure, so that it will dig a permanent foundation for such a structure, and that a sufficient number of improvement works have been built, and have been tested for a sufficient length of time, in the Mississippi and other rivers, to indicate the proper details of construction.

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PAPERS AND DISCUSSIONS.

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NOTES ON RAINFALL AT SAVANNAH, GEORGIA.*

By J. de Bruyn-Kops, M. Am. Soc. C. E.

The writer would not have deemed this paper of sufficient interest to present to the Society were it not for the fact that A. Prescott Folwell, M. Am. Soc. C. E., in a recent book* states that:

"Professor Talbot gives as a formula of maximum rates of rainfall in the eastern part of the country $R = \frac{105}{T + 15}$, which agrees quite closely with Plate IV, South Atlantic States, up to 30 min., but gives too small values for longer periods."

The curve on Plate IV, page 125, of that book shows "Rates of Rainfall Storms of the Second Class"; and, from the discussion at the bottom of page 56, it is inferred that "Storms of the Second Class" are those that give a certain rate of rainfall approximately five times in ten years, which is equivalent to once in two years. Now, as Savannah is about at the center of the territory named, this curve should apply to that city. The writer, therefore, compared it with some data he had worked out in 1896, while he was Assistant City Engineer of Savannah, and, finding that it did not agree with the results obtained at that time, he obtained from the United States Weather Bureau the data relating to all storms occurring during the years 1889 to 1906, inclusive, as recorded by the automatic rain gauge at Savannah, which

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*"Sewerage." 1907 Edition, Article 17, p. 45.

gave a precipitation equal to or greater than 0.25 in. in 5 min. or 0.75 in. in 1 hour. These data have been put into the shape here presented, in the hope that they may be found useful to others engaged in drainage works.

Referring to the quotations given above, it seems to the writer that such expressions as "in the eastern part of the country," and "South Atlantic and Gulf States" are entirely too comprehensive in their scope, and that it will be found that no single formula is even approximately correct for such a large area as that indicated; therefore, in promulgating such formulas, it should be distinctly stated from what data and locality they were deduced, as well as the method of deduction.

The following is the method of treating the data used by the writer: As received from the United States Weather Bureau, the data were in the form of accumulated amounts of precipitation for each 5 min. that the storm lasted; a sample case being that of the storm on December 8th, 1890, which is here reproduced:

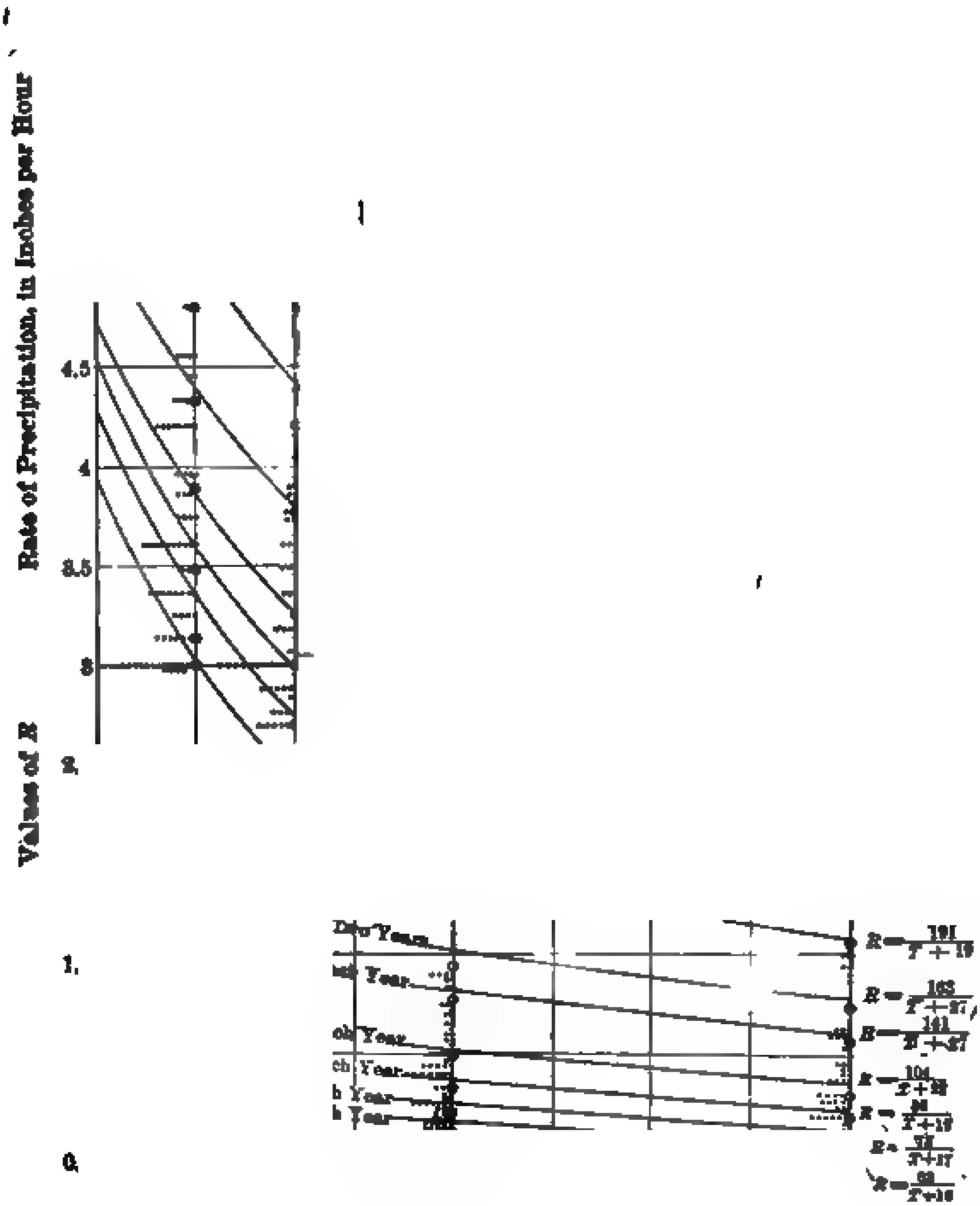
Minutes	5	10	15	20	25	30
Accumulated precipitation	0.20	0.32	0.50	0.75	0.95	1.03

Now, it is evident that the natural course of this storm presents rates of precipitation as follows:

Minutes	5	10	15	20	25	30
Accumulated precipitation	0.20	0.32	0.50	0.75	0.95	1.03
Rate, in inches per hour	2.40	1.92	2.00	2.25	2.28	2.06

The greatest rate of precipitation is 2.40 in. per hour for the space of 5 min. It has seemed to the writer, however, that the main consideration is not the rates of fall given by the natural course of the storm, but the maximum rates for the different durations; therefore, the storm data have been rearranged so as to exhibit this maximum, as follows:

Minutes	5	10	15	20	25	30
Accumulated precipitation	0.20	0.32	0.50	0.75	0.95	1.03
Precipitation in each 5 min	0.20	0.12	0.18	0.25	0.20	0.08
Maximum accumulated precipitation	0.25	0.45	0.68	0.75	0.95	1.03
Maximum rate of precipitation	3.00	2.70	2.72	2.25	2.28	2.06


Rate of Precipitation, in Inches per Hour
Values of R
4.5
4
3.5
3
2
1
0

The line marked "Precipitation in each 5 min." is obtained by putting in the 5-min. column the given accumulation for that period, then subtracting the given 5-min. accumulation from the given 10-min. accumulation and putting the result in the 10-min. column, and so on. The amounts in the line marked "Maximum accumulated precipitation" are: for 5 min., the amount precipitated during the period between 15 and 20 min.; for 10 min., the precipitation during the period between 15 and 25 min.; for 15 min., the precipitation during the period between 10 and 25 min.; and so on, selecting in each case the period, in any part of the storm, that gives the maximum precipitation for that period. In this manner, 162 storms were examined, being all that were reported by the United States Weather Bureau, for the years, and of the intensity, given. Table 1 shows the result of this investigation.

Two other points should be explained, in reference to the table: First, in tabulating the results of any storm which gave a greater rate of precipitation for a longer period than for a shorter one, the greater rate was tabulated for the shorter as well as for the longer period. For instance, in the storm of December 8th, 1890, it will be seen that the maximum rate for 20 min. was 2.25 in., while the maximum rate for 25 min. was 2.28 in. The rate has been tabulated as 2.28 in. in both cases, on the general grounds that if it rained at the rate of 2.28 in. for 25 min., it is reasonable to say that it rained at an equal rate for a less time.

The other point is, that all storms have been extended, from the point of their ending to the limit of time to which the investigation was carried (100 min.). This extension was made on the ground that if a storm gave, say, 0.5 in. of precipitation in 10 min. and then stopped, the effect on a drainage area in which the time of accumulation at the outlet was more than 10 min. would certainly be not less than if the same storm had precipitated 0.5 in. in the accumulation time of the area, whether it were 15 or 100 min.; and the probability is that it would be greater. In Table 1, therefore, the extended rates have been calculated on the total accumulated amounts as though they had been precipitated in the extended times. In order that these extended rates may be distinguished from the actual rates, they have been printed in italics.

In Plate CXIII have been plotted about one hundred of the highest

values for each 5-min. period, as taken from Table 1. At the maximum value, and from there counting downward 9, 18, 36, 54, 72, and 90, the plottings have been made larger than the others. As the number of years examined is 18, these large plottings indicate the rates of maximum storms and those occurring on an average of once in two years, and one, two, three, four, and five times each year. Through these points have been passed, with more or less success, regular curves, the equations for which are noted at the right of Plate CXIII.

The following comparison of Professor Talbot's "Maximum curve for the eastern part of the country," with the maximum curve for Savannah, Ga., as deduced by the writer, is of interest:

Minutes	5	10	15	20	25	30
Talbot............ $R = \frac{105}{T+15}$	5.25	4.20	3.50	3.00	2.63	2.34
Savannah .... $R = \frac{191}{T+19}$	7.96	6.59	5.62	4.90	4.34	3.90

Minutes	35	40	45	50	55	60	80	100
Talbot	2.10	1.91	1.75	1.62	1.50	1.40	1.10	0.92
Savannah	3.54	3.24	2.99	2.77	2.59	2.42	1.93	1.60

The comparison of Folwell's curve for "Storms of the second class for the South Atlantic and Gulf States," with the corresponding curve for storms occurring once in two years, as found for Savannah conditions, is also made so that the differences can be readily seen:

Minutes	5	10	15	20	25	30	35
Folwell	5.50	4.25	3.54	3.05	2.68	2.44	2.26
Savannah.. $R=\frac{163}{T+27}$	5.10	4.41	3.88	3.46	3.14	2.86	2.63

Minutes	40	45	50	55	60
Folwell	2.11	2.00	1.92	1.86	1.80
Savannah	2.44	2.26	2.12	1.99	1.87

As Folwell gives no formula for his curve, the evaluation was made from the curve shown on page 125 of the book previously quoted.

TABLE 1.—RATE OF RAINFALL AT SAVANNAH, GEORGIA (IN INCHES PER HOUR), AS RECORDED BY THE AUTOMATIC RAIN GAUGE OF THE U. S. WEATHER BUREAU, FOR ALL STORMS IN WHICH THE PRECIPITATION AMOUNTED TO 0.25 IN. IN ANY 5 MIN., OR 0.75 IN. IN 1 HOUR, DURING THE YEARS 1889 TO 1906, INCLUSIVE,

NOTE: The figures in italics show the extended rates, after the storm had stopped.

No. of Storm.	Date.	Duration of Periods, in Minutes.													
		5	10	15	20	25	30	35	40	45	50	55	60	80	100
1	June 27, 1889.	3.96	3.84	2.84	2.48	2.09	1.92	1.79	1.70	1.60	1.55	*1.41*	*1.29*	*0.96*	*0.77*
2	June 28, 1889.	2.98	2.04	1.76	1.62	1.44	1.30	1.29	1.22	1.14	*1.03*	*0.93*	*0.86*	*0.65*	*0.52*
3	July 6, 1889.	3.60	2.34	1.88	1.68	1.56	1.38	*1.18*	*1.04*	*0.91*	*0.83*	*0.75*	*0.69*	*0.53*	*0.41*
4	Aug. 6, 1889.	4.56	4.38	4.32	4.17	3.91	3.66	3.34	3.08	2.83	2.59	2.38	2.22	1.71	1.44
5	Aug. 8, 1889.	4.80	4.80	3.80	3.15	2.59	*2.16*	*1.85*	*1.62*	*1.43*	*1.30*	*1.17*	*1.08*	*0.81*	*0.65*
6	Sept. 1, 1889	4.20	3.90	3.80	*2.85*	*2.28*	*1.90*	*1.63*	*1.43*	*1.26*	*1.14*	*1.03*	*0.95*	*0.71*	*0.57*
7	Sept. 6, 1889.	3.60	3.30	2.80	2.52	2.14	1.90	1.72	*1.50*	*1.33*	*1.20*	*1.09*	*1.00*	*0.75*	*0.60*
8	May 3, 1890.	3.00	2.22	2.20	*1.65*	*1.32*	*1.10*	*0.94*	*0.83*	*0.73*	*0.66*	*0.60*	*0.56*	*0.41*	*0.33*
9	June 11, 1890.	3.60	3.00	2.60	2.25	1.92	1.70	1.55	*1.35*	*1.20*	*1.08*	*0.98*	*0.90*	*0.68*	*0.54*
10	June 20, 1890.	2.40	1.74	1.60	1.71	1.49	*1.24*	*1.06*	*0.93*	*0.82*	*0.74*	*0.67*	*0.62*	*0.47*	*0.37*
11	July 1, 1890.	3.00	3.00	2.40	*1.80*	*1.44*	*1.20*	*1.03*	*0.90*	*0.80*	*0.72*	*0.65*	*0.60*	*0.45*	*0.36*
12	July 3, 1890.	4.20	4.20	3.40	2.88	*2.30*	*1.92*	*1.65*	*1.44*	*1.28*	*1.15*	*1.05*	*0.96*	*0.72*	*0.58*
13	July 27, 1890.	3.36	2.98	2.28	1.86	1.56	1.40	1.24	1.11	1.00	0.91	0.91	0.91	0.91	0.79
14	Sept. 1-2, 1890.	2.40	1.62	1.36	1.30	1.18	1.00	0.93	0.93	0.88	0.82	0.77	0.73	0.71	0.63
15	Sept. 2, 1890.	3.00	2.70	2.20	1.86	1.66	1.54	1.44	1.32	1.21	1.18	1.05	0.99	0.91	0.87
16	Sept. 3, 1890.	2.28	1.44	1.08	0.87	0.79	0.77	0.77	*0.67*	*0.60*	*0.54*	*0.49*	*0.45*	*0.34*	*0.27*
17	Sept. 11, 1890.	3.00	2.04	1.64	1.32	*1.06*	*0.88*	*0.76*	*0.66*	*0.59*	*0.53*	*0.48*	*0.44*	*0.33*	*0.26*
18	Sept. 13, 1890.	2.40	2.40	2.00	1.95	*1.56*	*1.30*	*1.11*	*0.98*	*0.86*	*0.78*	*0.71*	*0.65*	*0.49*	*0.39*
19	Sept. 15, 1890.	1.80	1.80	1.56	1.38	1.22	1.10	1.00	0.92	0.85	*0.77*	*0.70*	*0.64*	*0.48*	*0.38*
20	Sept. 22, 1890.	2.40	1.80	1.24	*0.93*	*0.74*	*0.62*	*0.53*	*0.47*	*0.41*	*0.37*	*0.34*	*0.31*	*0.23*	*0.19*
21	Sept. 24, 1890.	2.64	2.40	2.28	2.31	2.16	1.94	1.98	1.98	1.98	1.82	1.61	1.40	1.28	*1.02*
22	Oct. 22, 1890.	4.20	3.60	3.12	2.76	2.38	2.02	*1.73*	*1.52*	*1.34*	*1.21*	*1.10*	*1.01*	*0.76*	*0.61*
23	Dec. 8, 1890.	3.00	2.70	2.52	2.28	2.26	2.06	*1.77*	*1.56*	*1.37*	*1.24*	*1.12*	*1.03*	*0.77*	*0.62*
24	May 27, 1891.	4.20	3.00	2.12	1.68	1.42	*1.18*	*1.01*	*0.88*	*0.78*	*0.71*	*0.64*	*0.59*	*0.44*	*0.35*

TABLE 1.—(*Continued.*)

No. of Storm.	Date.	Duration of Periods, in Minutes. 5	10	15	20	25	30	35	40	45	50	55	60	80	100
52	July 31, 1894.	3.60	2.40	2.08	1.71	1.56	1.38	1.27	1.20	1.18	*1.02*	*0.93*	*0.85*	*0.64*	*0.51*
53	Aug. 17, 1894.	3.84	3.72	3.60	3.18	2.88	2.58	2.36	2.15	2.00	*1.80*	*1.64*	*1.50*	*1.13*	*0.90*
54	Mar. 12, 1895.	2.64	1.62	*1.08*	*0.81*	*0.64*	*0.54*	*0.46*	*0.41*	*0.36*	*0.32*	*0.29*	*0.27*	*0.20*	*0.16*
55	Apr. 24, 1895.	2.76	1.89	1.60	1.38	1.22	1.08	1.04	1.00	1.00	1.00	1.00	1.00	*0.75*	*0.60*
56	May 24, 1895.	2.40	1.90	1.68	1.38	*1.10*	*0.92*	*0.79*	*0.69*	*0.61*	*0.55*	*0.50*	*0.46*	*0.34*	*0.28*
57	June 18, 1895.	3.36	3.00	2.68	2.46	2.11	*1.76*	*1.51*	*1.32*	*1.17*	*1.06*	*0.96*	*0.88*	*0.66*	*0.53*
58	June 16, 1895.	2.40	2.10	2.00	1.98	1.92	1.80	1.78	1.73	1.73	1.63	1.54	1.43	1.25	1.07
59	June 24, 1895.	2.64	2.22	2.00	2.01	1.73	*1.44*	*1.24*	*1.08*	*0.96*	*0.86*	*0.78*	*0.72*	*0.54*	*0.43*
60	June 30, 1895.	2.52	2.10	*1.40*	*1.05*	*0.84*	*0.70*	*0.60*	*0.53*	*0.47*	*0.42*	*0.38*	*0.35*	*0.26*	*0.21*
61	July 7, 1895.	2.76	1.80	1.60	1.35	1.18	*0.94*	*0.80*	*0.71*	*0.63*	*0.56*	*0.51*	*0.47*	*0.35*	*0.28*
62	July 12, 1895.	2.64	1.74	1.86	1.82	1.18	*0.94*	*0.80*	*0.71*	*0.63*	*0.56*	*0.51*	*0.47*	*0.35*	*0.28*
63	July 13, 1895.	6.60	6.00	5.60	5.10	4.32	3.64	3.18	3.02	2.87	2 68	2.43	2.28	1.71	1.37
64	July 26, 1895.	2.88	2.58	2.48	2.46	2.42	2.26	2.11	1.89	1.69	1.54	1.41	1.35	1.25	*1.12*
65	Aug. 8, 1895.	4.20	3.72	3.20	2.88	2.59	2.34	2.24	2.22	2.18	2.06	1.98	1.87	1.56	1.52
66	Aug. 4, 1895.	3.00	2.76	1.92	1.50	*1.20*	*1.00*	*0.86*	*0.75*	*0.67*	*0.60*	*0.55*	*0.50*	*0.38*	*0.30*
67	Aug. 17, 1895.	2.40	1.74	1.38	1.05	*0.84*	*0.70*	*0.60*	*0.53*	*0.47*	*0.42*	*0.38*	*0.35*	*0.26*	*0.21*
68	Aug. 22, 1895.	3.24	2.40	2.20	2.04	1.92	1.64	1.44	1.28	1.14	1.18	1.18	1.13	*0.99*	*0.79*
69	Aug. 23, 1895.	3.12	2.28	2.00	2.04	1.92	1.62	*1.39*	*1.22*	*1.07*	*0.97*	*0.88*	*0.81*	*0.61*	*0.49*
70	Apr. 24, 1896.	3.00	2.82	2.40	2.01	1.75	1.56	1.42	1.31	1.18	1.12	1.07	1.02	0.82	0.75
71	July 7, 1896.	4.20	3.60	3.40	3.00	2.52	2.16	1.89	1.67	1.49	1.36	1.24	1.15	0.98	*0.78*
72	Aug. 18, 1896.	3.00	3.00	2.85	2.85	2.40	*2.00*	*1.72*	*1.50*	*1.33*	*1.20*	*1.09*	*1.00*	*0.75*	*0.60*
73	Aug. 26, 1896.	4.20	3.78	3.48	3.21	2.86	2.60	2.44	2.24	2.02	1.88	1.74	1.63	*1.22*	*0.98*
74	Feb. 1, 1897.	3.00	1.98	1.52	1.26	1.18	1.08	1.00	0.93	0.84	0.82	0.78	0.76	0.68	0.59
75	Mar. 18, 1897.	4.56	2.64	2.04	1.74	*1.39*	*1.16*	*0.99*	*0.87*	*0.77*	*0.70*	*0.63*	*0.58*	*0.43*	*0.35*
76	Apr. 26, 1897.	3.12	*1.56*	*1.04*	*0.78*	*0.62*	*0.52*	*0.45*	*0.39*	*0.34*	*0.31*	*0.28*	*0.26*	*0.20*	*0.16*
77	June 15, 1897.	3.84	3.36	3.20	2.88	2.66	2.42	2.30	2.18	1.98	1.86	1.72	1.60	*1.20*	*0.96*
78	July 5, 1897.	1.92	1.74	1.68	1.68	1.51	1.48	1.55	1.50	*1.33*	*1.20*	*1.09*	*1.00*	*0.75*	*0.60*

TABLE 1.—(*Continued.*)

No. of Storm.	Date.		Duration of Periods, in Minutes.													
			5	10	15	20	25	30	35	40	45	50	55	60	80	100
25	July	18, 1891.	5.40	5.10	5.00	4.50	4.08	3.64	3.18	*2.78*	*2.46*	*2.22*	*2.02*	*1.85*	*1.39*	*1.11*
26	July	25, 1891.	3.24	2.58	*1.72*	*1.29*	*1.03*	*0.86*	*0.73*	*0.65*	*0.57*	*0.52*	*0.47*	*0.43*	*0.32*	*0.26*
27	July	26, 1891.	3.00	2.52	2.40	2.28	2.04	1.91	1.91	1.77	1.62	1.57	1.53	1.45	*1.08*	*0.87*
28	July	28, 1891.	3.00	2.88	2.64	2.25	2.23	2.02	1.94	1.74	*1.54*	*1.39*	*1.26*	*1.16*	*0.87*	*0.70*
29	Aug.	2, 1891.	2.40	1.86	1.52	1.44	*1.15*	*0.96*	*0.82*	*0.72*	*0.64*	*0.58*	*0.52*	*0.48*	*0.36*	*0.29*
30	Aug.	6, 1891.	3.00	2.40	1.88	1.53	*1.22*	*1.02*	*0.87*	*0.77*	*0.68*	*0.61*	*0.56*	*0.51*	*0.38*	*0.31*
31	Aug.	13, 1891.	3.84	2.82	2.48	2.31	2.16	1.94	1.74	1.58	1.50	1.48	1.38	1.30	*0.98*	*0.78*
32	Aug.	22, 1891.	3.50	3.20	3.20	3.00	2.59	2.40	2.11	1.91	1.71	1.57	*1.43*	*1.31*	*0.98*	*0.79*
33	Aug.	28, 1891.	6.00	4.50	4.00	3.60	3.24	2.90	2.58	2.24	2.01	1.84	1.69	1.60	1.60	1.51
34	July	18, 1892.	3.36	3.00	2.80	2.31	1.95	1.95	1.95	1.95	1.77	*1.60*	*1.45*	*1.33*	*1.00*	*0.80*
35	Aug.	10, 1892.	3.96	2.48	2.48	2.10	*1.68*	*1.40*	*1.20*	*1.05*	*0.93*	*0.84*	*0.76*	*0.70*	*0.52*	*0.42*
36	Sept.	12, 1892.	3.00	2.40	2.00	1.71	1.44	1.26	1.12	1.02	0.98	0.90	*0.82*	*0.75*	*0.56*	*0.45*
37	Sept.	19, 1892.	2.40	2.10	1.80	*1.35*	*1.08*	*0.90*	*0.77*	*0.68*	*0.60*	*0.54*	*0.49*	*0.45*	*0.34*	*0.27*
38	Sept.	20, 1892.	1.80	1.72	1.68	1.65	1.51	1.40	1.32	1.25	1.16	1.07	0.97	0.93	0.81	0.75
39	June	7, 1893.	3.12	2.46	2.24	2.10	1.87	1.62	*1.39*	*1.22*	*1.08*	*0.97*	*0.88*	*0.81*	*0.61*	*0.49*
40	July	15, 1893.	2.40	2.28	2.16	2.07	1.92	1.72	1.60	1.53	1.40	1.30	1.20	1.15	1.07	*0.90*
41	Aug.	3, 1893.	3.00	2.70	2.28	2.01	1.68	*1.40*	*1.20*	*1.05*	*0.93*	*0.84*	*0.76*	*0.70*	*0.53*	*0.42*
42	Aug.	14, 1893.	3.00	3.00	2.44	*1.83*	*1.46*	*1.22*	*1.05*	*0.92*	*0.81*	*0.73*	*0.66*	*0.61*	*0.46*	*0.37*
43	Aug.	20, 1893	3.48	3.24	2.40	*1.80*	*1.44*	*1.20*	*1.03*	*0.90*	*0.80*	*0.72*	*0.65*	*0.60*	*0.45*	*0.36*
44	Aug.	27, 1893.	2.64	2.52	2.20	2.04	1.92	*1.60*	*1.38*	*1.20*	*1.06*	*0.96*	*0.87*	*0.80*	*0.60*	*0.48*
45	Sept.	9, 1893.	3.36	3.00	2.85	2.85	2.66	2.52	2.34	2.27	2.26	2.22	2.18	2.15	1.83	1.57
46	Sept.	18, 1893.	2.40	2.28	1.92	1.86	1.73	1.62	1.53	1.41	1.33	1.22	1.13	1.05	0.83	*0.67*
47	Oct.	3, 1893.	3.60	3.60	2.88	2.34	2.24	2.34	2.03	1.86	1.82	1.72	1.59	1.49	1.33	*1.24*
48	Nov.	27, 1893.	3.00	2.40	2.00	*1.50*	*1.20*	*1.00*	*0.86*	*0.75*	*0.67*	*0.60*	*0.55*	*0.50*	*0.38*	*0.30*
49	June	23, 1894.	3.00	2.70	2.60	2.25	1.87	1.62	1.44	*1.26*	*1.12*	*1.00*	*0.92*	*0.84*	*0.63*	*0.50*
50	July	8, 1894.	2.64	2.10	1.44	*1.08*	*0.86*	*0.72*	*0.62*	*0.54*	*0.48*	*0.43*	*0.39*	*0.36*	*0.27*	*0.22*
51	July	18, 1894.	6.00	5.40	4.80	4.20	3.72	3.20	3.01	2.70	2.46	2.28	*2.07*	*1.90*	*1.43*	*1.14*

TABLE 1.—(*Continued.*)

No. of Storm.	Date.	Duration of Periods, in Minutes. 5	10	15	20	25	30	35	40	45	50	55	60	80	100
106	June 17, 1901.	3.60	3.44	3.42	2.76	2.21	1.90	1.86	1.71	1.68	1.55	1.47	1.40	1.05	0.84
107	July 8, 1901.	3.96	3.18	2.86	2.01	1.98	1.70	1.58	1.38	1.22	1.10	1.00	0.98	0.69	0.55
108	•Aug. 7, 1901.	2.40	2.36	2.36	2.19	1.85	1.54	1.32	1.15	1.02	0.92	0.84	0.77	0.58	0.46
109	Aug. 25, 1901.	4.56	3.84	3.24	2.88	2.38	1.94	1.66	1.45	1.29	1.16	1.05	0.97	0.73	0.58
110	Apl. 30, 1902.	1.80	1.68	1.60	1.44	1.44	1.36	1.36	1.36	1.24	1.15	1.11	1.07	0.95	0.76
111	May 19, 1902.	2.28	2.16	2.04	1.65	1.34	1.14	1.00	0.90	0.86	0.86	0.78	0.72	0.54	0.45
112	July 11–12, 1902.	5.88	4.02	3.96	3.66	3.29	3.19	3.19	3.02	2.85	2.71	2.58	2.42	1.88	1.51
113	July 13, 1902.	3.36	3.18	2.94	2.94	2.71	2.46	2.36	2.15	1.92	1.82	1.71	1.61	1.32	1.06
114	July 21, 1902.	3.48	2.88	2.12	1.86	1.61	1.36	1.16	1.02	0.90	0.82	0.74	0.68	0.51	0.41
115	July 27, 1902.	1.80	1.48	1.48	1.38	1.30	1.18	1.07	0.95	0.82	0.74	0.68	0.63	0.47	0.37
116	Aug. 11, 1902.	2.76	2.28	2.04	1.89	1.70	1.64	1.58	1.52	1.48	1.42	1.36	1.30	1.19	1.05
117	Aug. 28, 1902.	1.92	1.86	1.68	1.50	1.39	1.34	1.31	1.26	1.25	1.25	1.25	1.24	1.10	0.88
118	Sept. 9, 1902.	2.88	2.76	2.64	2.40	2.04	1.76	1.55	1.35	1.20	1.08	0.98	0.90	0.68	0.54
119	Dec. 3–4, 1902.	3.84	2.58	1.96	1.86	1.73	1.70	1.62	1.58	1.46	1.32	1.20	1.10	0.83	0.66
120	June 4, 1903.	3.12	2.76	2.40	2.01	1.68	1.36	1.16	1.02	0.90	0.82	0.74	0.68	0.51	0.41
121	June 8, 1903.	3.00	2.52	2.16	2.01	1.75	1.46	1.25	1.09	0.97	0.88	0.80	0.73	0.55	0.44
122	June 11, 1903.	2.64	2.28	2.00	1.86	1.58	1.52	1.39	1.25	1.10	1.00	0.90	0.83	0.62	0.50
123	June 18, 1903.	2.40	2.10	1.64	1.32	1.20	1.20	1.10	1.01	0.89	0.80	0.73	0.67	0.50	0.40
124	July 9, 1903.	3.72	3.66	3.40	3.30	3.00	2.78	2.63	2.42	2.24	2.15	2.00	1.91	1.58	1.46
125	July 22, 1903.	2.16	1.98	1.96	1.80	1.61	1.40	1.20	1.05	0.93	0.84	0.76	0.70	0.53	0.42
126	Aug. 15, 1903.	4.44	3.12	3.00	2.28	1.85	1.68	1.68	1.68	1.68	1.68	1.49	1.49	1.26	1.01
127	Aug. 31, 1903.	3.60	2.40	1.80	1.42	1.42	1.42	1.25	1.09	0.97	0.87	0.80	0.73	0.55	0.44
128	Sept. 2, 1903.	6.72	5.64	4.80	4.32	3.91	3.56	3.19	2.80	2.48	2.34	2.03	1.87	1.40	1.12
129	Oct. 16–17, 1903.	2.76	2.16	2.00	2.07	1.85	1.78	1.53	1.33	1.18	1.07	0.97	0.89	0.66	0.53
130	Nov. 4, 1903.	2.76	2.58	2.16	1.68	1.39	1.16	0.99	0.87	0.77	0.70	0.63	0.58	0.43	0.35
131	June 10, 1904.	2.52	2.34	2.16	1.95	1.82	1.64	1.46	1.26	1.13	1.02	0.93	0.85	0.63	0.51
132	July 10, 1904.	2.28	2.28	2.28	2.25	2.18	2.04	1.79	1.62	1.50	1.46	1.37	1.28	0.96	0.77

TABLE 1.—(*Continued.*)

No. of Storm.	Date.	Duration of Periods, in Minutes. 5	10	15	20	25	30	35	40	45	50	55	60	80	100
79	July 11, 1897.	7.80	6.48	5.28	4.29	3.48	2.90	2.49	2.17	1.93	1.74	1.58	1.45	1.09	0.87
80	July 22, 1897.	3.36	3.00	2.80	2.70	2.52	2.34	2.26	2.25	2.18	2.14	1.99	1.84	1.38	1.10
81	Aug. 14, 1897.	4.56	4.14	3.92	3.51	3.48	3.16	2.89	2.58	2.38	2.14	1.97	1.83	1.39	1.12
82	Aug. 15, 1897.	4.32	3.36	2.48	1.86	1.49	1.24	1.06	0.98	0.82	0.74	0.68	0.62	0.47	0.37
83	June 13, 1898.	2.76	2.46	2.12	1.83	1.68	1.48	1.32	1.15	1.02	0.92	0.84	0.77	0.58	0.46
84	June 19, 1898.	3.24	3.18	3.16	2.73	2.35	2.26	2.08	1.77	1.56	1.42	1.28	1.18	0.89	0.71
85	July 5-6, 1898.	2.64	2.34	1.96	1.74	1.46	1.22	1.04	0.92	0.81	0.73	0.66	0.61	0.46	0.37
86	July 12-13, 1898.	2.64	2.22	2.04	1.92	1.58	1.36	1.34	1.17	1.03	0.94	0.85	0.78	0.59	0.47
87	Aug. 1, 1898.	2.16	1.80	1.76	1.56	1.39	1.34	1.26	1.10	0.97	0.88	0.80	0.73	0.55	0.44
88	Aug. 4, 1898.	3.48	2.34	2.00	1.92	1.78	1.48	1.27	1.11	0.98	0.89	0.78	0.74	0.56	0.44
89	Aug. 16-17, 1898.	2.40	2.04	1.64	1.56	1.25	1.04	0.89	0.78	0.69	0.62	0.57	0.52	0.39	0.31
90	Aug. 16-17, 1898.	1.92	1.62	1.68	1.58	1.39	1.28	1.27	1.27	1.27	1.26	1.22	1.18	0.89	0.71
91	Sept. 4, 1898.	4.32	3.68	3.68	3.39	3.07	2.98	2.83	2.66	2.48	2.20	2.00	1.84	1.38	1.10
92	Sept. 8, 1898.	2.40	1.98	1.85	1.85	1.85	1.74	1.67	1.56	1.48	1.37	1.26	1.18	0.89	0.71
93	Mar. 23, 1899.	4.44	3.06	2.24	1.74	1.42	1.24	1.20	1.12	1.08	1.08	0.99	0.96	0.72	0.58
94	July 8-9, 1899.	2.64	2.10	2.00	1.42	1.42	1.28	1.20	1.17	1.10	1.08	1.02	0.99	0.74	0.59
95	Aug. 27-29, 1899.	2.52	2.28	2.08	1.88	1.82	1.70	1.58	1.47	1.38	1.32	1.25	1.19	0.89	0.71
96	Sept. 17, 1899.	2.28	1.80	1.48	1.41	1.39	1.18	1.15	1.02	1.02	0.95	0.86	0.79	0.59	0.47
97	May 18, 1900.	3.36	2.28	1.80	1.56	1.32	1.18	1.07	1.05	0.98	0.92	0.85	0.79	0.59	0.47
98	May 23, 1900.	1.92	1.68	1.52	1.20	1.04	1.04	1.04	1.04	1.04	0.95	0.87	0.81	0.61	0.49
99	June 24, 1900.	3.60	3.00	2.76	2.46	2.33	2.08	1.96	1.76	1.57	1.43	1.29	1.19	0.89	0.71
100	July 29, 1900.	2.52	2.04	1.64	1.38	1.18	0.98	0.84	0.74	0.65	0.59	0.53	0.49	0.37	0.39
101	Aug. 31, 1900.	2.76	2.52	2.00	1.71	1.49	1.30	1.20	1.10	1.01	0.91	0.83	0.76	0.57	0.46
102	Sept. 1, 1900.	2.46	2.04	1.80	1.58	1.34	1.20	1.10	0.96	0.85	0.77	0.70	0.64	0.48	0.38
103	Sept. 13, 1900.	3.72	3.06	2.68	2.19	1.75	1.46	1.26	1.09	0.97	0.88	0.80	0.73	0.55	0.44
104	Oct. 2-3, 1900.	2.64	2.52	2.16	1.71	1.39	1.18	1.16	1.16	1.16	1.16	1.16	1.16	0.96	0.95
105	Nov. 3, 1900.	3.12	2.60	2.60	2.49	2.16	1.92	1.76	1.76	1.60	1.55	1.48	1.34	1.16	0.93

TABLE 1.—(*Continued.*)

No. of Storm.	Date.	5	10	15	20	25	30	35	40	45	50	55	60	80	100
		Duration of Periods, in Minutes.													
133	July 24, 1904.	3.00	2.88	2.84	2.76	2.73	2.50	2.33	2.16	2.12	2.12	2.04	1.99	1.78	1.39
134	July 28-29, 1904.	3.72	3.36	3.16	2.37	1.90	1.58	1.36	1.18	1.05	0.95	0.86	0.79	0.59	0.47
135	July 28-29, 1904.	2.88	2.46	2.16	1.98	1.80	1.80	1.80	1.80	1.66	1.58	1.44	1.32	0.99	0.79
136	July 28-29, 1904.	4.80	3.96	2.88	2.88	2.71	2.44	2.20	1.92	1.70	1.54	1.39	1.28	0.96	0.77
137	July 28-29, 1904.	3.60	3.54	3.44	3.24	3.00	2.80	2.59	2.29	2.04	1.85	1.69	1.55	1.16	0.93
138	Aug. 8, 1904.	4.32	3.78	3.08	2.31	1.85	1.54	1.32	1.16	1.02	0.92	0.84	0.77	0.58	0.46
139	Aug. 22, 1904.	2.76	2.70	2.48	2.16	2.02	1.86	1.73	1.56	1.38	1.25	1.13	1.04	0.78	0.62
140	Sept. 6, 1904.	2.16	1.98	1.92	1.92	1.82	1.60	1.42	1.32	1.17	1.06	0.95	0.88	0.66	0.53
141	May 7, 1905.	4.20	3.48	2.72	2.64	2.64	2.58	2.39	2.25	2.14	2.04	1.95	1.85	1.39	1.11
142	May 21, 1905.	2.76	1.80	1.20	0.90	0.72	0.60	0.52	0.45	0.40	0.36	0.33	0.30	0.23	0.18
143	July 5, 1905.	3.12	3.00	2.44	1.98	1.73	1.44	1.23	1.08	0.95	0.86	0.78	0.72	0.54	0.43
144	July 6, 1905.	2.04	1.92	1.28	0.96	0.77	0.64	0.55	0.48	0.43	0.38	0.35	0.32	0.24	0.19
145	July 23, 1905.	3.72	1.98	1.32	0.99	0.79	0.66	0.57	0.49	0.44	0.40	0.36	0.33	0.25	0.20
146	July 25, 1905.	2.64	2.22	2.04	1.89	1.90	1.50	1.20	1.13	1.00	0.90	0.82	0.75	0.56	0.45
147	July 28, 1905.	3.96	3.40	3.40	3.39	3.22	2.82	2.68	2.34	2.07	1.87	1.70	1.56	1.17	0.94
148	Aug. 12, 1905.	4.92	3.18	2.12	1.59	1.27	1.06	0.91	0.80	0.70	0.64	0.58	0.53	0.39	0.31
149	Aug. 18, 1905.	4.68	3.90	2.60	1.95	1.56	1.30	1.11	0.97	0.86	0.78	0.71	0.65	0.40	0.39
150	Sept. 18, 1905.	3.00	2.70	2.68	2.61	2.40	2.00	1.72	1.50	1.33	1.20	1.09	1.00	0.75	0.60
151	Sept. 21, 1905.	2.88	2.76	2.72	2.58	2.50	2.18	1.96	1.71	1.51	1.37	1.24	1.14	0.86	0.68
152	Oct. 4, 1905.	3.36	2.94	2.68	2.16	1.87	1.66	1.42	1.25	1.10	1.00	0.90	0.83	0.62	0.50
153	Oct. 26, 1905.	1.80	1.68	1.48	1.38	1.32	1.22	1.04	0.91	0.81	0.73	0.66	0.61	0.46	0.37
154	Apr. 14, 1906.	4.32	3.48	2.68	2.49	2.18	1.82	1.56	1.37	1.21	1.09	0.99	0.91	0.68	0.55
155	June 27, 1906.	2.16	1.98	1.40	1.05	0.84	0.70	0.60	0.53	0.47	0.42	0.38	0.35	0.26	0.21
156	July 30, 1906.	1.80	1.62	1.40	1.05	0.84	0.70	0.60	0.53	0.47	0.42	0.38	0.35	0.26	0.21
157	July 30, 1906.	3.24	2.88	2.44	1.95	1.56	1.30	1.11	0.97	0.86	0.78	0.71	0.65	0.49	0.39
158	Aug. 23, 1906.	2.52	2.16	1.64	1.23	0.98	0.82	0.71	0.62	0.55	0.49	0.45	0.41	0.31	0.24
159	Aug. 27, 1906.	2.64	2.46	2.04	1.98	1.85	1.66	1.42	1.24	1.10	1.00	0.90	0.83	0.62	0.50
160	Aug. 28, 1906.	3.12	2.58	2.28	2.16	1.78	1.48	1.27	1.11	0.98	0.89	0.81	0.74	0.56	0.44
161	Sept. 5, 1906.	2.64	1.62	1.36	1.28	1.42	1.26	1.08	0.95	0.84	0.76	0.69	0.63	0.47	0.38
162	Sept. 26, 1906.	2.64	1.80	1.44	1.08	0.86	0.72	0.62	0.54	0.48	0.43	0.39	0.36	0.27	0.21

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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WATER PURIFICATION AT ST. LOUIS, MO.

Discussion.*

By Messrs. George A. Soper, G. C. Whipple, L. L. Tribus, and L. J. Le Conte.

George A. Soper, M. Am. Soc. C. E.—All should feel indebted to Mr. Wall for his description of the method of purifying the public water supply of St. Louis, and particularly for his description of the method of handling the large quantities of chemicals required. Mr. Soper.

As to the effects of the process, it seems to be too soon to form a final opinion. There have been abundant illustrations elsewhere of the usefulness of chemical precipitation, and of precipitation with iron and lime, but chemicals are generally used as a preliminary to filtration.

It will necessarily be some time before the sanitary value of the St. Louis works can be accurately measured. There is no doubt that the water has been improved, and improved materially, and apparently at a comparatively small cost; but the measure of that improvement depends on facts and figures which are not yet available. The speaker would like to see more analytical and statistical data concerning the effects of operation.

There are, of course, drawbacks to the use of chemicals, in treating a water supply. All these drawbacks are not self-evident. One objection results from the changes sometimes produced in the mineral content of the water. The speaker does not know that there has been any trouble with boilers or distributing pipes in St. Louis, but it is one of the things to look out for.

* Continued from November, 1907, *Proceedings*.

Mr. Soper. Considerable interest attaches to the author's remarks concerning the diminution in typhoid fever which seemed to follow the introduction of the plant. The use of typhoid statistics, in measuring the effect of an improved water supply, has many pitfalls and difficulties, and it would not be strange if the author had fallen into one or more of them. It is, unfortunately, unsafe to rely even on the vital statistics collected in many of the most advanced and best governed American cities, for, in the first place, physicians do not always know typhoid fever when they see it, and, in the second place, they do not always report it when they recognize it.

The speaker would like to know, if convenient to the author, how many cases of other fevers, which might have been typhoid, occurred during the period covered by his typhoid statistics. The statistics seem to be in error, because it appears that there has been a case mortality of from 14 to 25%, while it is probable that not more than 8% of all people attacked by typhoid die of it.

Even if the few statistics given were as accurate as could be desired, they would not of necessity show much of importance concerning the operation of the works. It is not easy to understand how much typhoid, in a city like St. Louis, is due to water. There are usually many other sources of this disease. It seems to be quite possible that, if all the facts were known, it would appear that the water supply of St. Louis has had in the last few years very little to do with the prevalence of typhoid, and that the disease has not increased or diminished to the extent commonly supposed.

There is a final point, which the speaker hesitates to mention, but inasmuch as, before this Society, it will probably be taken in the conservative spirit in which it is intended, and may lead to useful inquiries, it may be referred to briefly. It concerns the composition of the sulphate of iron used. How much iron is present, and how much acid? What is the quality of the lime? The chemicals cannot be pure. No city could afford to pay for pure chemicals, even if they were obtainable. What are the impurities? How much arsenic is there in this sulphate? Some years ago the speaker had occasion to examine specimens of sulphate of aluminum from a good many filter plants, and found arsenic in nearly all of them. It is true that, usually, the arsenic was not present in large quantity, but it was easily discoverable, and in some of the samples it was present in sufficient amount to be of more than passing interest. The arsenic, of course, came from the sulphuric acid used in making the sulphate of aluminum, the sulphuric acid having been produced from pyrites which contained arsenic.

Mr. Whipple. G. C. Whipple, Assoc. M. Am. Soc. C. E.—There are a number of questions that the speaker would like to ask in regard to this interesting paper, especially as to the details of the method by which the

chemicals are applied to the water. He is more interested, however, in the general principles of the process and in the results, than in the details. This method of purification by chemical precipitation is usually regarded as a preliminary process, to be followed by filtration; but in this case the preliminary process is stretched so as to perform all the work that is done. The results which have been accomplished by this stretching of a preliminary process are of great interest, and no doubt the people of St. Louis appreciate very much the improvement that has been made in the quality of their water supply. Mr. Whipple.

It seems to the speaker, however, that the author takes altogether too roseate a view of the future. For instance, near the close of the paper is found this statement:

"With these basins in service and the improved facilities for uniform treatment afforded by the new coagulating plant, there is no reason to doubt that St. Louis will be supplied with water as agreeable to the eye and as pure and wholesome as is enjoyed by any city in the United States."

This is certainly an exaggeration. The speaker cannot believe that the results of this process are going to be as good as the results which would be obtained by supplementing chemical coagulation with filtration, according to modern methods; and it does not seem to him that the figures presented in the tables bear out the statement just quoted. In the early part of the paper the author speaks of the tap water in St. Louis in 1904 as being clear and sparkling. To translate this into the language used by the chemist would be to say that the water had a turbidity of zero. The tables in the paper show that the turbidity of the water has not always been zero, but often far from it; or rather, they show that the suspended matter has not been zero, for it will be noticed that figures for the turbidity of the tap water are not given at all. They are simply given for the water before treatment. The speaker hopes that, in his closing discussion, the author will supply this deficiency.

Of the few analyses given, some are monthly averages, and others were taken a week apart. Now, it is a well-known fact that a monthly average often does not tell what the condition of the water has been from day to day. The figures for a month may be fairly low and satisfactory, and yet there may have been days during that month when the water was not satisfactory. This the speaker knows from experience, and there is no reason to believe that it is not true of the St. Louis water. That the product of such a plant as this would be irregular, would naturally be expected, for while the application of the chemicals may be under control, the natural physical and meteorological conditions which affect the sedimentation are not subject to control.

The speaker had the pleasure of visiting the St. Louis plant, during the early part of the work, at a time when it was not working as

Mr. Whipple. well as it evidently has been lately, but he then saw an illustration of its irregularity. For the month of June, 1904, the amount of suspended matter in the effluent is given in Table 1 as 39 parts per million, and yet on the day when the speaker was there the turbidity of the water leaving the settling basins was 400. Therefore, it seems to the speaker that the figures given may be, to a certain extent, a little misleading, and may give an idea that the water is clearer than it sometimes really is. Countenance is lent to this view by reports which have come from persons who have visited the city and who, while they remark that the quality of the water has been very greatly improved, speak of its occasional turbidity.

The speaker agrees with Dr. Soper that the data are hardly sufficient to give the water supply an absolutely clean bill of health, and that they do not show what may be the final results of this treatment, from a sanitary point of view. The figures, admitting their accuracy, do show a great reduction in the typhoid fever death-rate, but if one were to follow the typhoid fever records back for a number of years before those tabulated, he would find that about ten years ago the typhoid fever death-rates were nearly as low as they have been during the last year or two, and that this was during the time when the city was depending on plain sedimentation, without the use of chemicals, for the purification of the supply.

Here it should be noticed that the author refers to the efficiency of the old sedimentation process as being "from 10 to 80 per cent." Now, the report of the commission which studied the water supply in 1904 gave the efficiency of the settling basins as "from 75 to 94%," and gave the average efficiency as 85%, while, if the speaker recollects correctly, later observations made by Mr. Fladd showed the efficiency of the sedimentation process without chemicals to be more than 90%, a figure which comes closer to the figures given for the chemical process in the paper.

The speaker mentions these matters because it seems to him that this paper might be made of very much greater value, and certainly much more convincing, by giving more detailed information regarding the quality of the treated water. Some of the omissions were doubtless accidental, for the author speaks in one place of tables giving the results of turbidity, and in another place of tables giving the results of tests for *B. Coli* and other tests, which data are not found in the places mentioned.

One other point might be mentioned, namely, the effect which the use of these chemicals may have on the mineral quality of the water. It is well known that, where lime is used, the reaction is not instantaneous, and there are apt to occur what are known as "after deposits" of calcium carbonate, etc. These deposits may take place after the water has left the settling basins. The speaker once visited a city where there were considerable deposits of lime on the inner

surfaces of the service pipes and on the working parts of meters. These deposits were not very large, but were quite noticeable. There is no reason to doubt that in time this will happen in St. Louis. Mr. Whipple.

The question of the quality of the ferrous sulphate used has been raised by Dr. Soper. This is an important matter, for the chemical may conceivably contain substances which may be detrimental to the pumps through which the water passes.

In conclusion, the speaker wishes to congratulate the City of St. Louis for what its engineers have done. They deserve praise for the energetic manner in which they have taken hold of the problem. He hopes, however, that the city will not content itself with a half-way process, but will use as much energy in securing a complete process of purification as it has used in developing this preliminary process of chemical precipitation.

L. L. Tribus, M. Am. Soc. C. E.—The speaker has read this paper with considerable interest, and desires to call attention to one thing in particular—and a very commendable matter, at that. While St. Louis was discussing, and had been considering for years, the question of an improved water supply, with experts from all over the country, Boards of Trade, Chambers of Commerce, citizens, etc., yet no one seemed to be able to suggest any really practical method of doing the work, until the gentlemen mentioned in this paper, having to meet the situation, designed a plant which has done the work, and has given water of vastly better quality than that with which the city had ever been supplied. That is a true engineering feat, and deserves high praise. Mr. Tribus.

It is very probable—and the speaker does not disagree with either Mr. Soper or Mr. Whipple—that better results can be secured by carrying the process forward, by filtering the water after it passes through the sedimentation tanks, or by greater chemical refinement; but the main point stands out that the engineers met a difficult situation, and built a practicable plant in a short time, and at a comparatively small cost.

L. J. Le Conte, M. Am. Soc. C. E. (by letter).—This problem has engaged the closest attention of engineers for many years, and the general conclusion has been that sedimentation—followed by coagulation and filtration—was the proper solution. The expense of such purification approximates from \$15 to \$17 per million gallons. Mr. Le Conte.

The author's recent experience at St. Louis, however, seems to show that, for all practical purposes, the whole operation can be performed successfully by coagulation, followed by prolonged sedimentation, thus apparently shutting out entirely the expensive necessity for filtration. According to his experience, the water can be purified for \$5 per million gallons. Of course, all have understood, heretofore, that it is physically possible to accomplish the entire operation of

Mr. Le Conte. clarification by coagulation and subsidence; but it has always been maintained, with much force and judgment, that it was unwise to do so, on a large scale, because a considerable portion of the coarser sediment could first be removed more cheaply and successfully by plain subsidence, and, most important of all, that the last traces of clay particles could be more completely removed by filtration than by a prolonged settling.

Furthermore, engineers have generally held that good reliable sanitary requirements, as to bacterial efficiency, could best be accomplished and properly maintained by filtration. The author now states that the same bacterial efficiency can be had by simple coagulation and prolonged subsidence, and that the result is accomplished at one-third the cost. This is a most important fact. It would appear, however, by reference to the various tables submitted, that, in point of fact, the clarification is not by any means such as would be desired by a fastidious community. The average "color" is given as 10 to 12, whereas the effluent from good filters generally shows 0 to 5. That is to say, it is more than four times as cloudy as good filtered water.

Table 4 shows that in November, 1906, and in January and February, 1907, the bacterial efficiency was below standard, and that in March, 1907, for the first time in three years' operations, it was above standard. That is to say, from a sanitary point of view, the water delivered to consumers was unsafe most of the time except during the last month of operations.

It would be interesting to know whether or not the maximum quantity of sulphate of iron (3.75 gr. per gal.) and the maximum quantity of lime (11.0 gr. per gal.) used during the third year of operation were actually consumed during March, 1907, when the bacterial efficiency was satisfactory.

The writer is greatly impressed by the good results in Table 2, showing the reduction in the typhoid death-rate due, undoubtedly, to water purification. This feature, above all others, appeals to one's sense of humanity. The results stand out in strong contrast with the late experience in Washington, D. C., where, apparently, the filters failed to lower the typhoid death-rate, as was reasonably expected.

There is no doubt, however, that the bacterial efficiency attained in the St. Louis experiments is practically all that could be desired, from a sanitary point of view, and the expense incurred, namely, $4.62 per million gallons, is only about one-third of that of good filtered Mississippi River water.

The whole question, then, turns upon the degree of clarification necessary or desirable in each case. Each city is now at liberty to decide for itself according to its financial ability, and later, perhaps, when better able to stand the extra burden, may introduce filtration. This will prove to be particularly good news to many western cities now supplied with muddy river waters.

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THE BRACING OF TRENCHES AND TUNNELS, WITH PRACTICAL FORMULAS FOR EARTH PRESSURES.

Discussion.*

By Messrs. H. P. Moran, E. W. Stern, G. L. Christian, V. H. Hewes, E. P. Goodrich, J. F. O'Rourke, O. F. Nichols, and W. H. Gahagan.

H. P. Moran, Esq. (by letter).—In the construction of the Brooklyn Subway, with which the writer is connected, it was necessary to excavate a trench averaging 30 ft. deep and 5 000 ft. long. The bank was composed of sand and gravel with some few boulders. The bracing, designed by Mr. Meem, had the larger braces at the top and smaller braces when approaching the bottom. In no single instance has any failure of the lower and lighter braces been observed. Many instances of bending of the upper rangers, however, have been noticed. Mr. Moran.

In reconstructing the Hanson Place sewer, the trench excavated was 45 ft. deep, and there were seven sets of rangers; the larger ones being at the top. It was noticed that the top rangers had bowed at various places, the lower four rangers remaining perfectly straight. Great care was always taken to prevent any movement of the bank during the process of bracing.

It seems obvious to the writer that, under similar conditions of fill, the greatest pressure will always come at the top.

A permanent structure, such as a retaining wall, should be designed to withstand the maximum thrust of the earth. One should determine: First, the total pressure; second, its line of action; and third, its point of application. Obtaining the total thrust, it is evident that as the lever arm is increased, the overturning moment becomes greater.

* Continued from November, 1907, *Proceedings*.

Mr. Moran. If the point of application be taken as two-thirds of the distance from the bottom, the maximum overturning moment will be obtained.

Comparing the thickness of a rectangular wall, designed, first according to Mr. Meem's method, and second, according to current practice as represented by Trautwine, it is found that, for a masonry wall, the thickness in the first case will be 46% of the height, no allowance being made for wall friction; in the second case it will be 35% of the height.

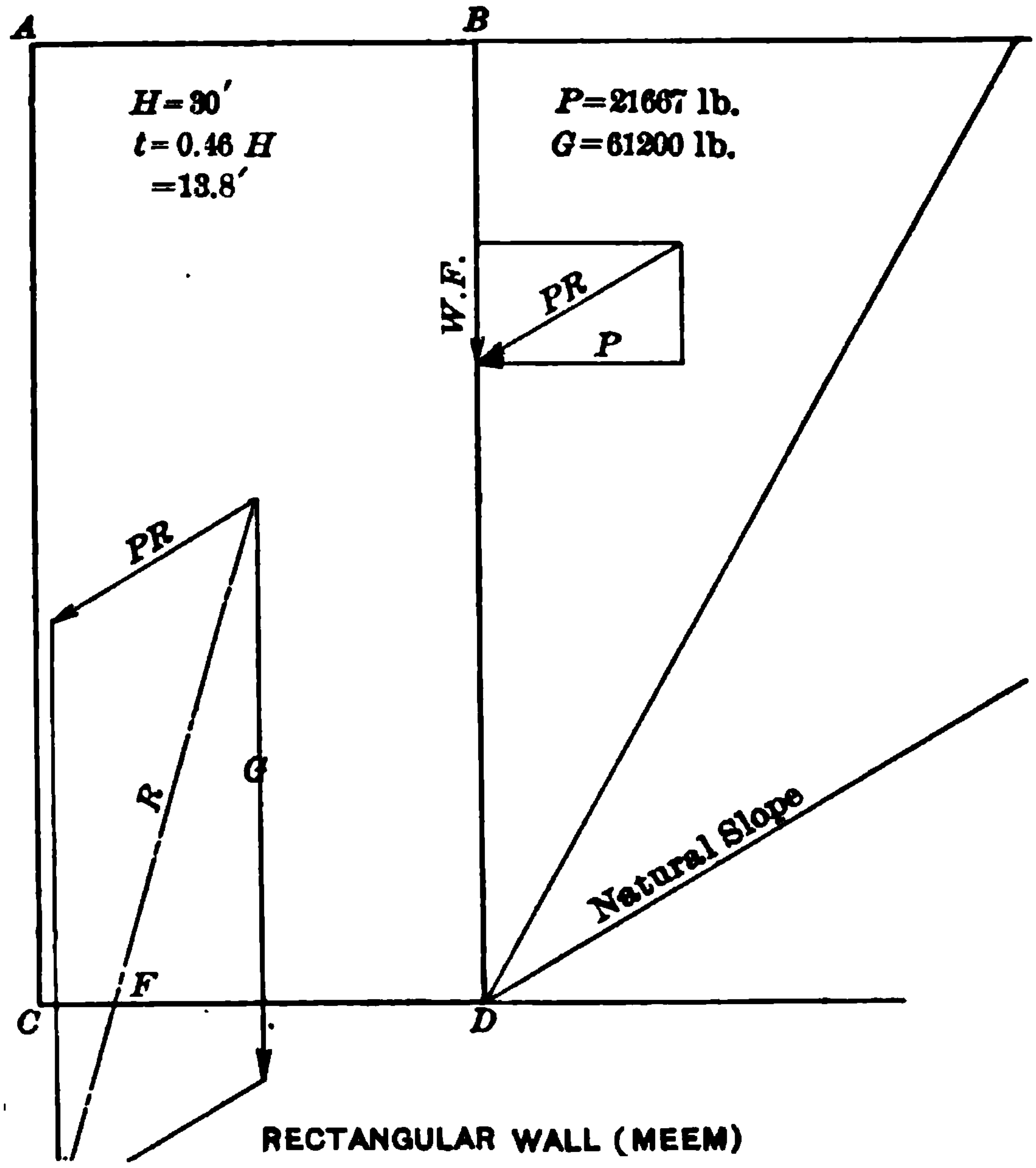


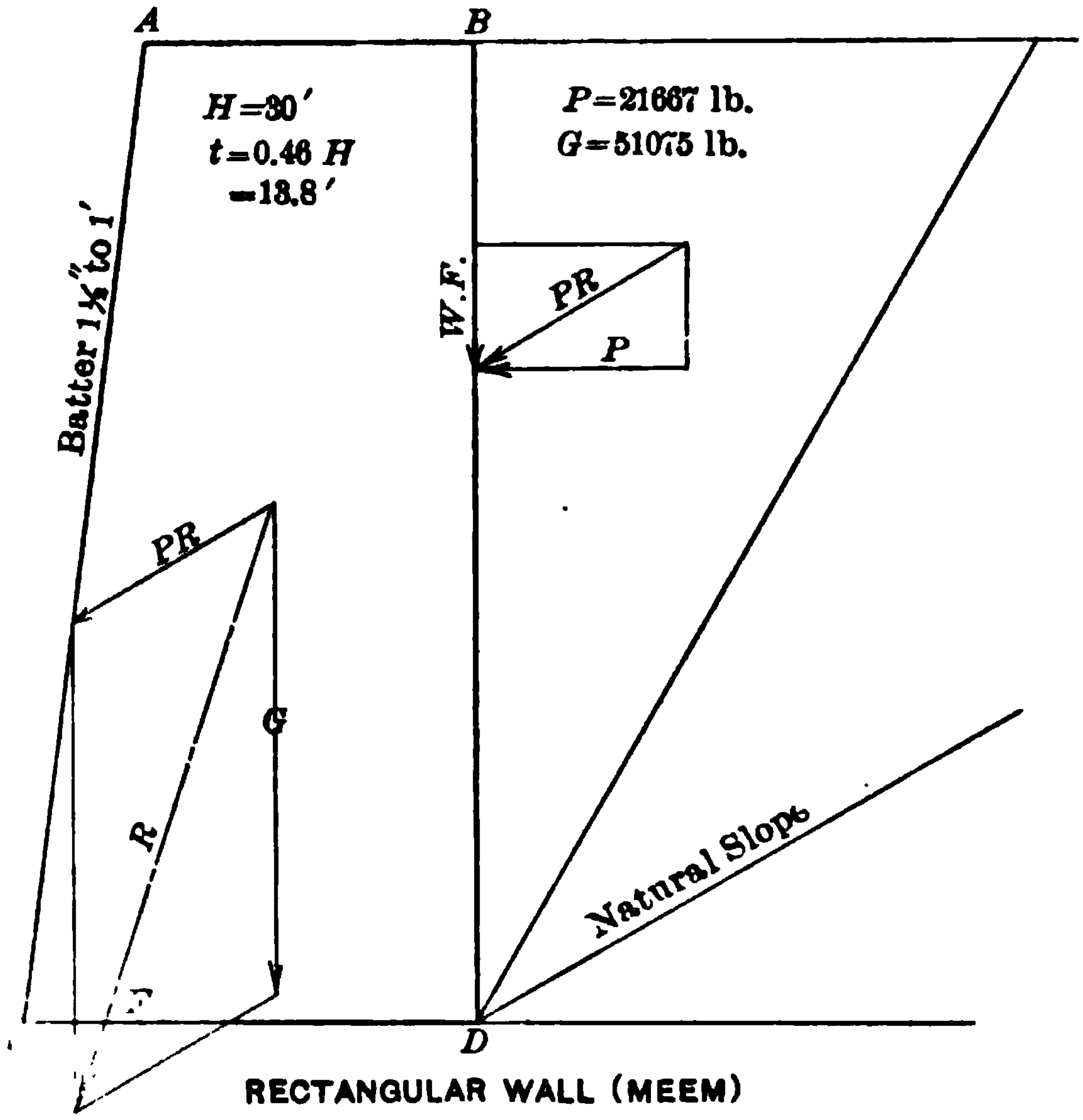
FIG. 45.

Fig. 45 shows graphically a wall designed according to Mr. Meem's theory, with allowance made for wall friction. Fig. 46 shows the same wall with a batter of 1½ in. per ft. Fig. 47 shows a wall having a thickness of 35% of the height (current practice), checked graphically by the same method. In Fig. 47 the resultant passes outside of the toe, indicating that the stability of the wall is questionable, and that excessive pressure would come upon the toe of the wall.

The numerous failures of retaining walls, 90% of which are supposedly due to improper foundations, can be readily explained when considered in the light of Mr. Meem's theories.

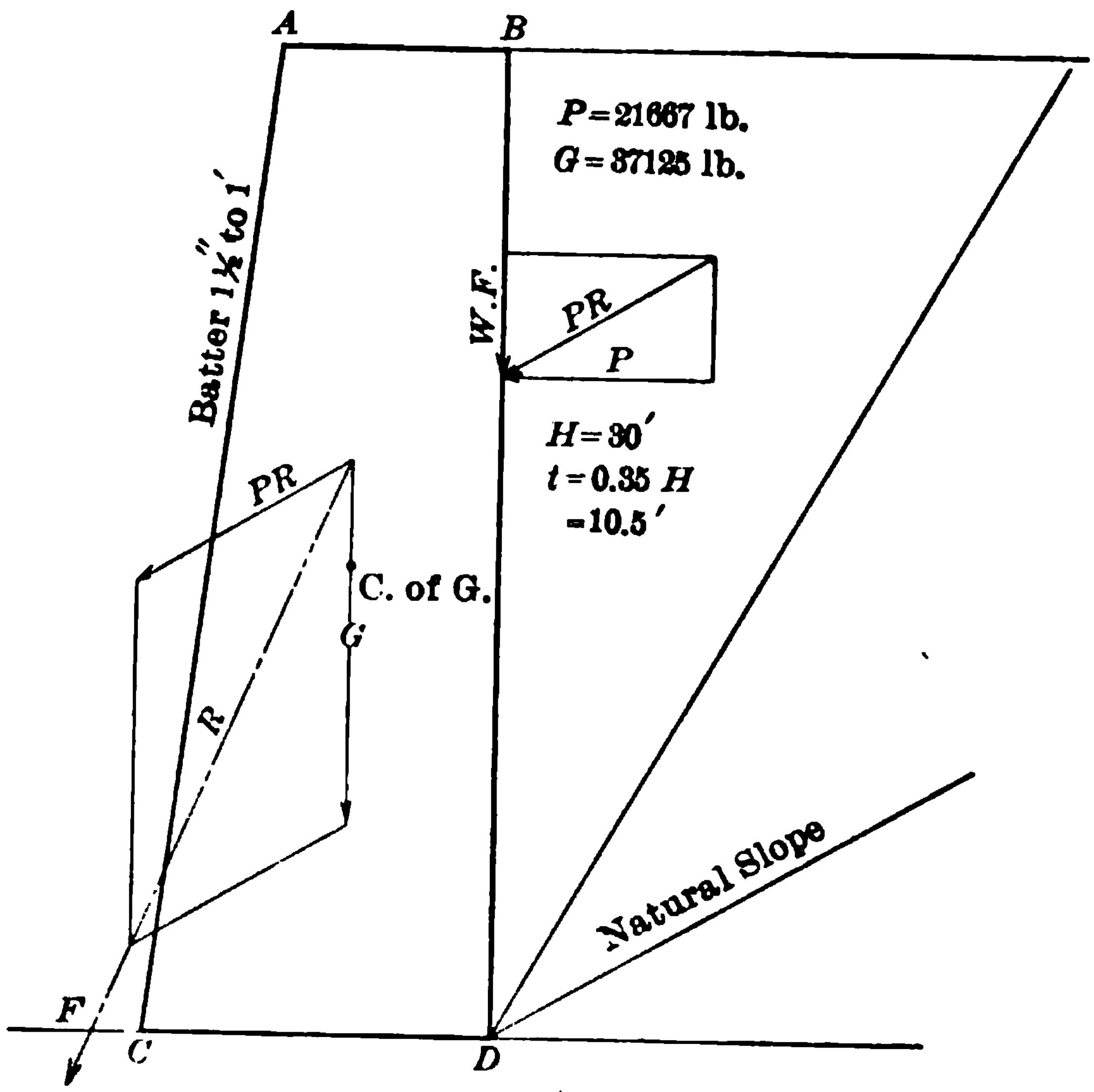
A retaining wall with buttresses presents a different problem—one analogous to that of a sheeted trench. Here the buttresses correspond to the braces, and the wall to the rangers. The wall, therefore, can be designed as a beam, in horizontal sections, to resist sliding and shearing. The overturning force is resisted by the buttresses.

Mr. Moran.



RECTANGULAR WALL (MEEM)

Fig. 46.



WALL (BY TRAUTWINE)

Fig. 47.

Mr. Moran. The pressure varying as the square of the height, and the point of application being two-thirds up from the bottom, gives a wall, triangular in section, having the thickest part at the top and diminishing to zero at the bottom. Practically, it need not be so, and an average thickness could be taken, on the ground that the earth will not only arch itself vertically, but also horizontally, having its springing line at each buttress.

In the case of a reinforced concrete wall with buttresses, the increased strength required at the top could be easily obtained by spacing the horizontal reinforcements closer at the top, and increasing the spacing when approaching the bottom.

A reinforced wall with counterforts tied securely presents a similar problem, where the wall itself can be considered as a beam. As before, the spacing of the horizontal rods should increase as the bottom is approached.

From an analysis of the foregoing examples, the writer concludes that the total force acting cannot be determined by Coulomb's wedge of maximum thrust. This is based primarily upon the assumption that the surface of rupture is a plane. He considers that the surface of rupture is curved, probably parabolic in outline. Using this assumption as a working basis, the total pressure acting two-thirds up from the bottom will be less than the amount obtained by Mr. Meem's straight-line formulas.

Mr. Stern. EUGENE W. STERN, M. AM. SOC. C. E.—The practical experiences recounted by Mr. Meem are extremely interesting and valuable, but the formulas advanced by him do not appeal to the speaker, who still has faith in Coulomb and Weyrauch.

Mr. Meem's conclusions are based on experience in excavating and tunneling through a sandy material under almost ideal conditions. The street paving would prevent the earth below it from becoming saturated with rain water, and the small amount of water which might get through would be very quickly dispersed through the sandy soil, and would be just sufficient to "temper" it nicely.

Altogether different experiences have been obtained in going through a clay or loam soil, which would tend to hold and absorb water. A dry clay bank would stand almost vertically, and if excavations were made through it in perfectly dry weather, such as might obtain in the western arid portions of the United States, where practically no rain falls during the summer, it might be safe to carry out deep excavations with practically no sheeting or bracing whatever. But, as soon as the soil becomes saturated with water, the conditions are entirely different, and instead of its holding an almost vertical face in excavation, it will assume an angle of repose sometimes considerably less than 30 degrees. Now, the surface water cannot get into the soil all at once; it will have to work in gradually, the top

layers becoming saturated first. The pressure on the bracing, therefore, would be greater at the top than at the bottom at first, but, this seepage continuing, it would be found later that at the bottom the pressure was very much greater than at the top. Recently, the speaker had a case which illustrates this point admirably. An excavation for a trench was made in clay soil in dry weather, and the sides were almost vertical. As a precautionary measure, sheeting was put in, with cross-braces. Owing to the negligence of the contractor, only one line of these braces was put in, about half way up from the bottom. A heavy rain fell during the night, and the sheeting was pushed close together at the bottom and out at the top, showing very clearly that the pressure at the bottom was greater than at the top. Mr. Stern.

Another experience by the speaker was in connection with the abutment of a bridge which he was called upon to reconstruct. This abutment, supporting a fill of about 20 ft., was built in the summer, in dry weather, and the filling, consisting of clay loam, was completed also during dry weather. The abutment held up perfectly until the following spring, and then, the clay bank having been saturated with water, and no adequate provision having been made to withdraw this from behind the abutment, it bulged at about one-third of its height above the bottom, showing that the pressure at this point was greatest. This experience is not in accord with the author's formula.

The speaker, also, cannot agree with the theory advanced by Mr. Meem as to the pressure above the roofs of tunnels. He states that the less the angle of repose, the less the pressure will be upon the roof of the tunnel, so that a material like very fine sand, of which the angle of repose is, say, 20°, would cause small pressure, and a material in which the angle of repose is much greater, clay and loam soil, for instance, would cause a greater pressure. If, for the sake of argument, the material had no angle of repose whatever, or practically none—approximating then the condition of a fluid, the molecules of which are frictionless or nearly so—there would be still less pressure on the roof of a tunnel, according to Mr. Meem; with which contention the speaker cannot agree, as this is exactly the opposite of the facts. In the latter case, the pressure is the greatest that can possibly be obtained.

The late Sir Benjamin Baker, Hon. M. Am. Soc. C. E., in a paper, read before the Institution of Civil Engineers many years ago, on the "Actual Lateral Pressure of Earthwork," mentions an interesting case in driving a heading for the Metropolitan Railway. He says:

"The ground consisted of sand and ballast, heavily charged with water, overlying the clay through which the heading was driven, at a depth of 44 feet from the surface. After the heading had been completed some months, the clay became softened to the consistency of putty by the water which filtered through the numerous fissures, and

Mr. Stern. the full weight of the ground took effect upon the settings. Both caps and side trees showed signs of severe stress throughout the entire length of the heading."

This is an interesting example of a condition in which, at the start of the work, the angle of repose of the material being great, the pressure on the roof and sides of the tunnel was not large, but, as soon as the soil became saturated with water, and the angle of repose consequently became very much less than it was originally, the pressure increased enormously.

The speaker believes that the earth over the roof of a tunnel acts as an arch. The greater the angle of repose the material has, the more readily the earth arches, and the greater its strength. The less the angle of repose, the less readily it arches, and the less its strength.

In connection with earth pressures, it is rash to draw any broad conclusions from special experiences, for the reason that the conditions of the soil may vary, and the seepage of water has such an extremely important effect that great variations in pressures may result from these causes. A homogeneous clay in which there is no sand whatever will act differently from one in which there are pockets of sand, or which has gravel or sand overlying it, and entirely different from sand alone, or sand and gravel, and these materials when saturated with water will again act differently. Practical formulas to suit all these conditions would be an impossibility.

The observations of Mr. Meem as to pressures against braces, deduced from his own work, are no doubt correct, but these do not prove that the theories of Weyrauch and Coulomb are wrong. Theory, to be applied properly to a particular case in practice, must take into account all the conditions. Now then, what are the unknown elements in earth pressure?

Eliminating the question of water pressure in the soil, for the sake of argument, and having given the height of the bank, the only point that is uncertain is the angle of repose, and unless the angle of repose is known absolutely, of course, theory and practice cannot be made to agree.

The error most commonly made in applying theory to practice is the assumption that the angle of repose remains constant, no matter what the depth; this, of course, is not tenable. There is no reason why it should be constant, and every reason why it should not be.

In soil that has stood for ages in its original condition, the lower layers will be very much more compacted than the upper ones, by reason of the pressure of the earth above. If excavation is carried deep enough, it is found that the earth is almost in the condition of rock, it is so compactly consolidated. By applying sufficient pressure to a sample of earth, say in a hydrostatic press, it would be possible to make it almost as firm as soft rock.

The angle of repose, therefore, would increase with the depth below the surface in some proportion as the compactness of the soil increased. This condition would apply, not only to clay and loam, but also to sand, when not under the water line. Mr. Stern.

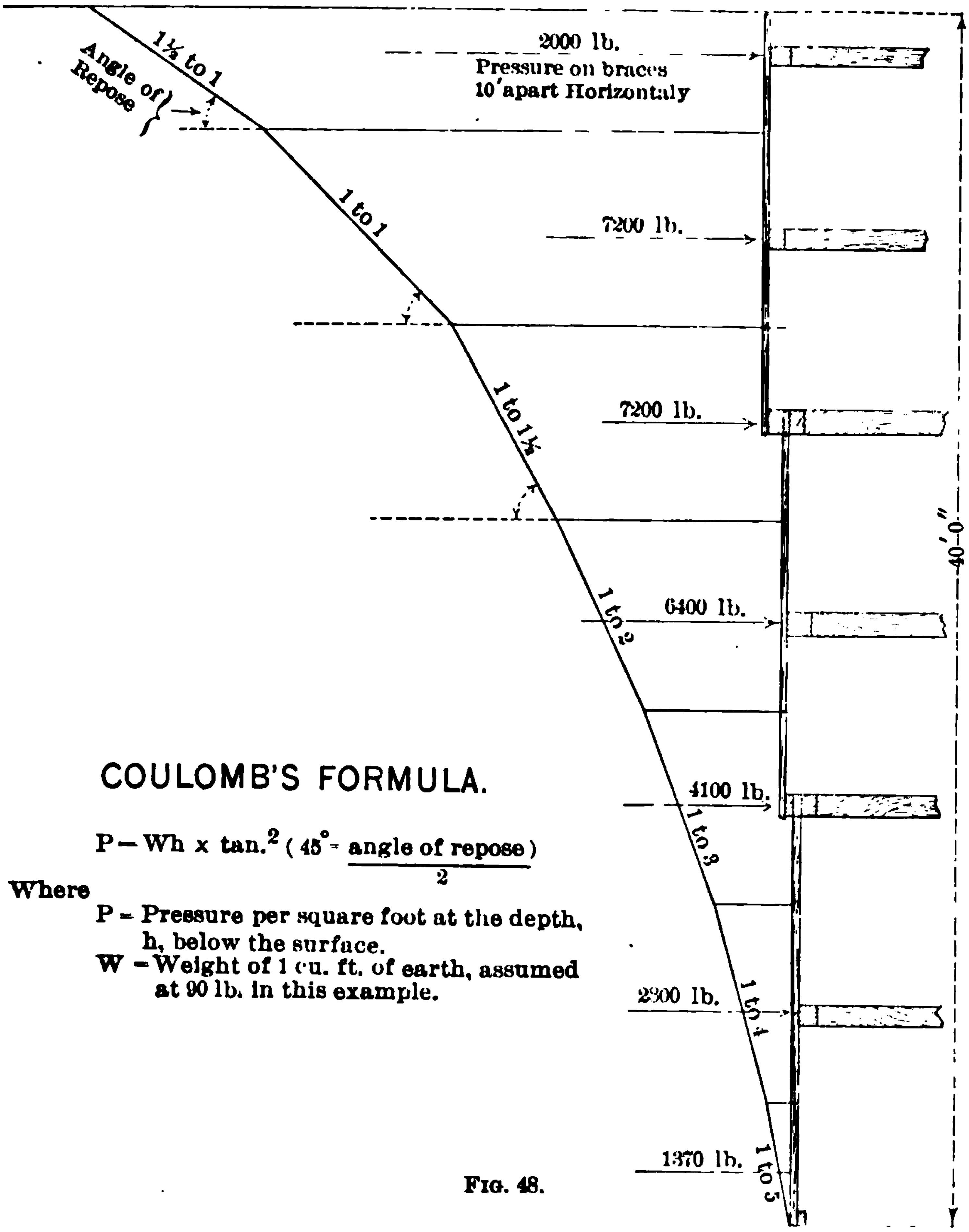


FIG. 48.

Take the case of an excavation through coarse sandy soil in which there is a very small quantity of loam (this is almost always the case). The soil below the surface is usually damp. At the surface, the angle of repose may be 1½ horizontal to 1 vertical. At a depth of 40 ft. below the surface, it may be 1 horizontal to 5 vertical. In clay soil it may be 1 horizontal to 3 vertical near the surface, if dry, and 3 horizontal to 1 vertical if wet, and 20 ft. below, 1 horizontal to 6 or 8 vertical.

Mr. Stern. Now, if the horizontal pressures are computed by Coulomb's theory, on this basis, for the same trench that Mr. Meem has given in his example, Fig. 7, the angle of repose varying gradually from 1½ horizontal to 1 vertical at the surface to 1 horizontal to 5 vertical at 40 ft. below, the pressures on the braces are found to be as shown in Fig. 48.

These pressures, with the exception of that in the top brace, which is less, agree so closely with those given by Mr. Meem that his practical observations do not prove that Coulomb's and Weyrauch's theories are wrong.

The question now arises: Of what practical use are the formulas advanced by the author? Are they sufficiently correct to be used generally? The speaker thinks not. In his opinion, they are of limited application, and—most important of all—the principles enunciated are radically wrong.

Mr. Christian. G. L. Christian, M. Am. Soc. C. E.—Mr. Meem is to be congratulated on his paper, relating to a subject upon which little is written. He has evidently given it much thought, guided by his valuable practical experience.

The speaker has in mind two retaining walls (neither of which was designed by engineers) varying in height from 5 to 15 ft. They were observed for more than twenty years, and, in that time, gradually failed in places, by bulging, usually at one-third the height, although occasionally the bulge appeared at one-half the height. The bulging in any particular place was always very slow, and was not sufficient to be noticeable unless several years had elapsed between observations. In the course of time, the parts of the wall where bulging had occurred collapsed.

The speaker once had occasion to place some extra braces across a trench, about 20 ft. wide and of the same depth, in a somewhat clayey soil, and instructed that they be placed pretty well toward the bottom. This did not agree with the ideas of the superintendent for the contractor, who claimed that the greatest pressure was near the top. This was a theory which the speaker had never heard advanced before, and did not believe in then, nor does he now; but he had a good deal of faith in the practical ability of the contractor's representative, and as it was very important that the banks be held rigidly in place, the safe course was adopted of putting in the additional timbers near the top as well as near the bottom.

The speaker does not agree with Mr. Meem's theory that the deeper the trench the lighter should be the lower bracing, although possibly that might be so, provided the trench is sheeted well and there are absolutely no voids behind it. Under those conditions, the author's argument is probably valid, but fails immediately on the appearance of voids, or very soon thereafter.

Fig. 1.—West Heading, Morris Avenue, Webster Avenue Storm Relief Sewer, Bronx Borough, New York City.

Fig. 2.—Looking East from West Heading, Morris Avenue, Webster Avenue Storm Relief Sewer.

The question resolves itself into whether or not it is practical to excavate in any soil and not leave voids, or opportunities for voids to occur behind the sheeting. The speaker thinks it is not. Mr. Christian.

It would seem that the sheeting on each side of a trench is subjected to the same thrusts as those on a retaining wall in the same position; therefore, as it is necessary to make the wall thicker at the bottom, it follows that the bracing should be designed to withstand the same pressures, and, therefore, must be heavier at the bottom than at the top.

Fig. 49.

In the Borough of The Bronx, New York City, the Webster Avenue Storm Relief Tunnel Sewer is now being driven. Much of the tunnel work passes through a very much decomposed dolomite rock resembling clay. In such places the tunnel has been driven and timbered by the crown-bar method referred to by the author. In this work, a top heading was first driven, as shown by Fig. 1, Plate CXIV. The cap and legs are shown in Fig. 49, the latter by the dotted lines, *A*.

Fig. 49 is an actual cross-section taken on this work. The two

Mr. Christian. center crown-bars are placed in position and held up by the posts, *B*, and then blocking and wedging are driven between the crown-bars and the caps, after which the legs, *A*, are removed. Transverse lagging is next driven above the crown-bars, as shown, after which the next two bars are put in position and held up by the posts, *C*. Transverse lagging is then driven above these bars in the same manner as before, the excavation underneath proceeding meanwhile, after which the two remaining bars are placed in position and held by the posts, *D*. The sides are then lagged; excavation is made for the wall-plates, which are then set to line and grade; and then the segmental arch is placed in position and blocked tightly against the crown-bars, the posts, *B*, *C*, and *D*, being taken out as the work advances.

A good example of this work is shown by Fig. 2, Plate CXIV. In the background may be seen the completed segmental arches, while in the foreground is shown much of the advance timbering just described, *i. e.*, the crown-bars above and their supports, the posts, *B*, showing on the left, and *B*, *C*, and the bottom of *D* on the right.

The bench is next excavated, and then the wall-plates are underpinned, where necessary, after which the work looks like that shown in Plate CXV.

Mr. Hewes. V. H. HEWES, M. AM. SOC. C. E.—The speaker has become greatly interested in the several points brought out in the discussion, and would call attention to the general practice of miners in timbering. After having placed the timbers, the miners proceed to wedge them up so thoroughly that they fairly ring when struck with a hammer. By striking them in this way, they test them to see if the work has been properly done. Thoroughness in wedging is of the greatest importance, for, if there should be any slackness in the timbering, it would allow a movement to take place in the supported material. Should any movement occur, enormous pressure would be developed, often so great that, even if solid cribbing were placed in the workings, the timber would be crushed down.

Several years ago the speaker visited an old Mexican coal mine, then being worked by the fuel department of an American railroad. The timber in the rooms had been removed and the pillars robbed. This brought on what was termed a crush, or squeeze, and no amount of timbering could be placed in the workings to stop it. The only recourse was to run new entries, leaving a considerable body of coal between the workings and the new entry; even then, there was evidence of the movement by the cracking sound given out along the entry.

Evidence of the great pressure exerted by a mass of material which has been disturbed is often shown by the caving in of a mine. The speaker had occasion to go to the 200-ft. level of a mine, where a cave had taken place. The ore was soft hematite. In driving into the

PLATE LXV.
PAPERS, AM. SOC. C. E.
DECEMBER, 1907.
CHRISTIAN ON
EARTH PRESSURES AND BRACING.

WEBSTER AVENUE STORM RELIEF SEWER, BRONX BOROUGH, NEW YORK CITY.

U of M

broken ore at this level it had become so solid and compact that it was impossible to tell which was "unbroken ground" except by following the track rails, which were still in place. It was necessary for the miners to shoot it, in the same way as they would virgin ground. Mr. Hewes.

In an open trench or excavation, if not timbered, the ground in most cases starts to move at or near the surface, and fills up the trench, while that near the bottom may never move. The ground at the top has nothing to hold it in place and prevent its movement, while that at the greater depth is held in place by the material above it. To prevent any movement taking place, timbering is used; and Mr. Meem's experience, that the greatest pressure comes nearer the top of the trench, would not hold when any movement takes place at greater depth, for, in such cases, which often happen, much heavier timbering is required at the bottom than near the top.

E. P. Goodrich, M. Am. Soc. C. E.—This paper should be given much credit, but, at the same time, it is open to considerable adverse criticism. The author presents a number of exceedingly interesting and instructive examples illustrating actual practice in the bracing of trenches and tunnels, but his theories seem to be open to grave question both from theoretical and experimental standpoints. Mr. Goodrich

It is a well-known fact that freshly cut masses of earth of certain kinds will stand for considerable periods with very steep slopes, but, in most cases, it may prove exceedingly dangerous to take advantage of this phenomenon, in an effort to reduce the size and quantity of timbering used to brace those banks. Where the earth is contained in a street, between cellar walls carried to fair depths, and is of a naturally porous nature, some allowance may be made without much risk; but, where work is carried along a side hill, for instance, in a clayey soil, a similar procedure might result in serious damage and loss. Consequently, it is the speaker's opinion that the author's several ideas and recommendations should be adopted only where conditions make them manifestly applicable, as approved by experienced engineers, and that they should not in any wise be considered as of general application.

In a few instances, in the speaker's experience, he has encountered earth pressures which were evidently greater near the ground surface than at lower levels. On the other hand, the opposite condition has been observed in a considerably greater number of cases, and numerous experiments of a very careful nature have shown the close agreement between fact and theory in this regard. These seemingly contradictory observations may be partly explained as follows:

When sheeting is driven along the side of a trench, the earth behind the sheeting is more or less loosened and otherwise disturbed; movements of greater or less magnitude may take place, in the form of slips, sprawling or crawling; cracks or voids may be formed, allow-

Mr. Goodrich. ing further movements to take place, etc. Such action may be very slow in culminating, but is almost sure to happen with lapse of time and variations in humidity. Furthermore, it is an observed fact that when large breaks occur, they are likely to take place along a curved surface, such as shown diagrammatically in Fig. 50. This fact is recognized by several authors of earth-pressure theories, and is the basis of the theory presented in the discussion of this paper by Mr. Haines.

Now, in dry soils, when the toe is prevented from sliding, a mass may crack away from the bank and tilt over at the top, turning about the toe, as shown in an exaggerated manner in Fig. 51. Such action would account for the cracks often found at various distances back from the edge of an excavation, though they may also be produced by local settlement, or by several other causes. It would also throw the heaviest stresses into the upper braces, and would tend to confirm the author's theories. On the other hand, if the toe is not so well fixed, and if the soil is more humid, a slip is likely to take place, as shown in an exaggerated manner in Fig. 52. This is the usual condition, and, obviously, would produce maximum stresses in the lower braces.

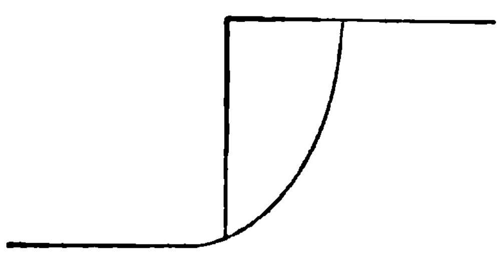


Fig. 50.

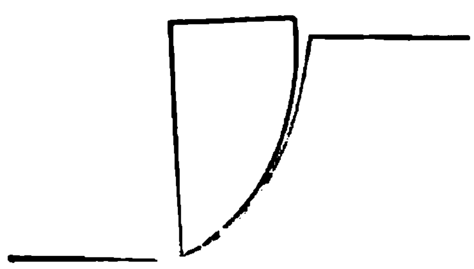


Fig. 51.

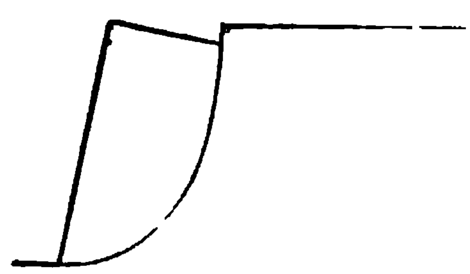


Fig. 52.

Again, many soils will "crawl" or appear to flow, acting like a viscous material. For such conditions, the theory advanced by the author would seem untenable, because both vertical and lateral pressures are then proportional to the depth. Damp clay is such a material, while dry clay may possess considerable cohesive strength. The speaker has seen tunnels driven through clay, and these have stood, for days at a time, for considerable distances and heights, without support and without change. In other cases, he has known the sides of similar tunnels to stand without material change of form, but to move bodily inward with such force as to crush to pulp the ends of heavy timbers. In another case, he was called to examine a tunnel and the nearby buildings, where the sides of the brick tunnel lining had been crushed inward, allowing a movement of the soil which endangered the foundations of even relatively distant buildings. The humidity of the soil had been greatly increased by the bursting of a sewer, thus producing unexpected conditions of stress which were quite extraordinary, but evidently also really possible. The two last

mentioned cases are explainable only by such theories as developed by Rankine; and those of the author would prove entirely inadequate. The latter must evidently be qualified most carefully as to the period of time which can elapse, the conditions of humidity, the kind of soil, etc. Mr. Goodrich.

This qualification is actually made by the author in several instances, thus showing the pertinence of the speaker's criticism.

On page 607,* the author says, "where the trench does not have to stand too long." On page 617,* he advocates maintaining "some sort of a bench at or near" the toe of the bank inside the sheeting. This seems to be inconsistent, when viewed in the light of his statement on page 604,* that "the lower part of a trench may be left unsheeted." On page 611,* he qualifies the application of his theories to clays, by saying that they "frequently develop pressures by squeezing or sliding horizontally, for which it is difficult to provide." On page 600,* however, he has endeavored:

"to develop a practical basis in connection with which it will be possible at all times to effect an approximate reconciliation between the actual conditions of stability of earth and the theoretical formulas or resultants arising therefrom."

The qualifying statements introduced by the author seem to place his theory, also, among those which he condemns as not being able "to reconcile the theoretical with the practical conditions."

Again, on page 612,* Mr. Meem speaks of a "frictionless material" having "an angle of repose" greater than zero. This is an obvious inconsistency, and when a zero angle is properly applied to the condition being discussed by the author, his seemingly logical deduction as to the weight coming upon the top of a tunnel would lead to an infinite value, which could not possibly obtain.

The author's deduction, on page 614,* that earth will arch around a circular manhole with the same perfection at "indefinite depths," as close to the surface, does not seem compatible with the physical conditions which must exist in an arch formed in a granular mass. It is true that such materials will form effective arches over considerable spans, with certain sizes of grains and conditions of humidity, friction, or cohesion. For example, wheat will often arch completely across the ordinary elevator bins, and the effects on each other of loaded piles driven in soft ground show analogous action over distances of 20 ft. or more. Most earth-pressure experiments also confirm these observations, but to push, as far as the author has done, any deductions as to the effects of arch action, seems like exceeding the limits set by facts and sound theories. Because various large voids may have existed for long periods is not deemed a sufficient premise for all the conclusions reached. On page 613,* the author does not give any definite

**Proceedings*, Am. Soc. C. E., for August, 1907.

Mr. Goodrich. limit beyond which "the * * * arching effect is destroyed," and the arch action considered on page 610* can take place only over certain spans, the limiting value of which is not stated. This seems to be a most important omission, except that it is believed by the speaker that conditions are so variable that no precise limit can possibly be set in either instance. It would thus appear necessary in the first instance almost invariably to use for shafts such "bracing" as would be used "in an open trench," as suggested by the author for large shafts.

The author's reasoning on pages 611 and 612,* as to the effects of the angle of repose on arch action, is not at all clear. Furthermore, it seems to be based on entirely wrong assumptions, when the author states that there can exist a "tendency to slide along the angle of repose," using this phrase as he does synonymously with that of the "natural slope of the earth," as on page 600*. The experiments made by the speaker, and reported to the Society in his paper on "Lateral Earth Pressures and Related Phenomena,"† are believed to have demonstrated the existence of an angle of internal friction along which sliding will take place, which angle is usually very different from the angle of natural surface slope. Consequently, the author's work must be at least so modified as to include this angle of internal friction.

The ideas set forth by Mr. Haines approach nearer to those of the speaker than those of any investigator on this interesting subject. The speaker, also, has measured numerous slips—natural, and made by experiment—but has not found the hemispherical surface as accurately followed as one might infer was always the case, from Mr. Haines' descriptions. Arch action along lines which closely approximate circles is usually present in most soils, as soon as any movement takes place, and in this special point, such earth masses act like solids. But vibration, changing humidity, natural settlement, and lateral pressures bring about further movements among the particles composing the mass, so that an action closely analogous to the slow flow of a viscous mass also often takes place. Mr. Haines, however, takes no account of these possible changes of condition with lapse of time, although this is absolutely necessary in a complete theory. To be sure, a retaining wall which is stable under the author's or Mr. Haines' assumptions will be apt to stand under conditions like those usually assumed, but it does not seem to be good engineering to waste material in securing a needless excess of stability, as would seem to be the case in designing by either of the two theories mentioned.

As opportunity offers, the speaker is working out the combined theories of the several actions which occur in masses of earth, and hopes some time to present them for discussion. He doubts Mr.

**Proceedings*, Am. Soc. C. E., for August, 1907.
† *Transactions*, Am. Soc. C. E., Vol. LIII, p. 272.

Mr. Goodrich.

Haines' analysis on page 1006,* which includes simply the volume and surface of a sphere. If the earth mass were supported on a shaft through the point, *B*, of Fig. 28, the reasoning might apply, but the mass which eventually moves actually rests with considerable weight on the earth beneath, which remains in position. Consequently, other forces besides pure shear enter the problem, and the speaker believes that Mr. Haines' explanation of the spherical surface of slip is not sound.

As to his analysis of the stresses due to the arch action, as he supposes it, attention should be called to the fact that the "center of gravity," as he expresses it, does not coincide with the center of length, as shown in Fig. 32, so that the stress, *T*, as found by him, is smaller than it should be according to the method he has adopted. There is also a grave doubt in the speaker's mind whether it is even approximately correct to assume that the lateral stresses against trench sheeting are such as would be produced by a series of arch rings between which no friction exists. It would seem rather more nearly according to reason and fact to assume a single ring of some thickness, just above the surface of fall, which ring is assumed to carry the weight of all the earth above it. This supposition would explain the shrinkage away from the sheeting near the surface, which the speaker saw on one occasion, coexistent with evidences of considerable arch action near the bottom. It also explains the concentrated pressures observed by the speaker on several occasions, and gives a reason for the fact that practically no pressure is found at the top of the sheeting, where it should be a maximum, according to the theories of the author and Mr. Haines.

Time, however, modifies most things, and it would not seem improbable that such concentrations would eventually distribute themselves, more or less, according to some law of variation of pressure. Such a readjustment of stress (described later) has actually been observed by the speaker.

An entirely satisfactory earth pressure theory has still to be evolved, and more phenomena can be explained on the assumption that earth acts like a viscous, partially elastic material, than on any other supposition. This hypothesis explains all the author's observations; explains the phenomena described above; and also throws light on the change in the position of the point of maximum thrust and the distribution of pressures observed by the speaker during one of the many earth pressure experiments he has made. The conditions and methods of test and analysis are given in the speaker's paper on Earth Pressures, previously mentioned. The initial observations showed a roughly triangular distribution of stress. A special condition was soon brought into play by a sharp thaw in the material be-

* *Proceedings*, Am. Soc. C. E., for November, 1907.

Mr. Goodrich. hind the wall, and a considerably increased and practically concentrated load was observed near the top of the embankment. The point of application of this concentrated load then appeared to move slowly downward and was finally lost in the slightly parabolically distributed continuous load.*

While Mr. Meem is a most successful practitioner, and has done some very exceptional work, his theories with regard to earth pressures are not considered as well worthy of praise. It seems to the speaker, rather, that much more work must be spent on the problem before it is entirely solved, and that other lines than those followed by the author will lead to more consistent results. What might be called "Rankine's theory applied to a viscous granular material, wherein angles of internal friction are used," appears to be the most profitable course along which to investigate earth pressures and related phenomena.

Mr. O'Rourke. J. F. O'Rourke, M. Am. Soc. C. E.—The speaker has had a great deal of trouble in trying to do timbering work according to theory. Mr. Meem's conclusions are largely according to his experience in dry, sandy and gravelly material. It is only necessary to examine his diagram, Fig. 7, in which the pressures are indicated by parallelograms, with the largest parallelogram on top, to commence at once to find fault with his theory.

It is only necessary to consider that these pressures are transmitted through the material to show that it is impossible, at the top of an earth strut, so to speak, to get the greatest pressure, or a sufficiently great pressure, to require 12 by 12-in. timbers. If there were such a pressure as that, the material itself would rise, and the pressure would disappear. The fact is that in most cases this top timber may be taken out (barring, of course, strains which may be caused by other things than the pressure of the earth).

The real trouble with timbering, and all this protection of excavation, is that where there is something besides dry sand or gravel, there is water to be dealt with, and then the material has varying friction, and, of course, varying pressures.

The speaker had cases on Park Avenue, New York City, where 12-in. I-beams were bent. These beams were set vertically, and were perfectly straight until the ground had become more or less wet, and commenced to take a totally different angle of friction, thus becoming what is called "heavy."

With the statement that the pressures are the reverse of those caused by water, the speaker cannot agree at all. His experience is that it is almost impossible to drive sheathing beyond a certain depth because of the great pressure that develops the farther it is driven, and the fact that the timbers incline inward at the bottom owing to the increased pressure. No one who has done much sheet-piling in

* *Transactions*, Am. Soc. C. E., Vol. LIII, Figs. 11 to 16, p. 278.

excavations, particularly where there was water, will contradict that statement. It is a universal condition. Mr. O'Rourke.

The general question of experiments in earth pressures and their conditions which will reduce the subject to a science, is an admirable one. The speaker's opinion, however, is that such experiments would have to be continued for a thousand years in order to obtain something in the nature of a formula, but that formula would have a great many constants. There might be a number of what might be described as arbitrary, unknown quantities, but having had a thousand years' experience, it is possible that one might learn to use them. However, notwithstanding the great success in the use of formulas, up to the present time, the better plan is to stick as closely as possible to big timber, no matter what the formula indicates.

O. F. Nichols, M. Am. Soc. C. E.—In dealing with what may be called non-fluid earth, a semi-dry or quite dry material, not like a fine sand which will run, but more like the sand and loam found in New York City and on Long Island, there is much of value in the suggestions made by Mr. Meem. Mr. Nichols.

The angle of repose is determined by allowing material to run free in the open air; but, when it is flowing on itself, and has an angle of internal friction, so to speak, there is no doubt that the friction of the material tending to slide downward would set up some other angle of repose, or of partial stability, greater than the normal angle of repose and corresponding more nearly with the angle which Mr. Meem establishes as bisecting the complement of the angle of repose. Just what this angle is, is indeterminate, but, assuming that material does act in this way, the speaker has no doubt that Mr. Meem is right, that there is some arching effect with the skewback on one side which may be taken as the angle of repose, and on the other side by the sheeting of the trench.

This arching effect produces great pressure on the sheeting at or near the surface of the ground, and correspondingly relieves the pressure on the sheeting at points below, until, at the bottom of the sheeting, it is very often possible to undercut the sheeting, and to do this undercutting for long distances, and even to a great depth.

This arching effect, so far as it obtains, necessitates the use of heavier timbers at the top and lighter timbers at the bottom of the trench, and, where the material is not too wet and is not allowed to stand too long, so that water, the atmosphere, and other agencies can act on it, it is quite possible to leave the sheeting out for certain distances near the bottom of the trench. Constructors take advantage of this fact, for there is very seldom any shoring at the bottom of sheeting under the conditions assumed.

Engineers, however, must err if possible on the safe side, and it is probable that the old "angle of repose" conditions will still be used in

Mr. Nichols. earthwork calculations, mainly because it must be assumed that the worst conditions may prevail.

A man—who, of course, was not an engineer or in any way connected with engineering—recently asked for a discrimination between men like the late Professor Bartlett, of West Point, the engineer of to-day, and the contractor. The answer should be that men like Professor Bartlett develop the laws by which the forces of Nature act on material, the engineer applies these laws, and the contractor adds to the knowledge of the engineer the saving grace of common sense, and, particularly, introduces the element of commercial values.

When, therefore, engineers become successful contractors, the combination should, at least theoretically, redound to the great good of the community. The questions and solutions which Mr. Meem offers in his interesting paper are especially those with which engineering contractors should be familiar, and it is to be hoped that such men will take part in this discussion, for they, like Mr. Meem, have fought out engineering battles in close contact with the materials themselves, with their ears close to the ground, and they are men who measure problems by the laws of profit and loss as well as by those of engineering skill and efficiency.

The work in this field which Mr. Meem has done in Brooklyn, in supporting nearly a mile of elevated railway in full operation, in addition to the surface of the street and one of the busiest sets of trolley tracks in the world, and the work he did in restoring the grade on the Brooklyn end of the Battery Tunnel, certainly mark him as an expert in engineering construction, and his paper should be of great value, especially in bringing out discussion.

Mr. Gahagan. WALTER H. GAHAGAN, M. AM. SOC. C. E.—Those who have recently passed along Fulton Street and Flatbush Avenue, in Brooklyn, N. Y., cannot but admire the skill with which the subway work on these thoroughfares has been conducted. Credit for this work must be given to Mr. Meem, Chief Engineer for the contractors. The elevated railroad structures on these streets, from the City Hall to the Long Island Railroad Station, have been supported on temporary columns, for the full length of the excavation, and there have been no slips or settlements of the columns, and no interruption in the use of the tracks of the surface or elevated railroads.

Mr. Meem discusses pressures in dry, homogeneous earth, which conditions were found by him on this work, but, if hydraulic conditions are introduced, it becomes more difficult to determine the effect on the materials to be handled. The variety of materials is great, in all cases; they may be homogeneous, or may be mixed in any proportions, and may run through all gradations from dry to very wet.

The author does not intend that his formula for bracing, etc., shall be applied to all these various conditions, but only to cases where

the material is reasonably dry and homogeneous. Under other conditions, the speaker would be inclined to follow Mr. O'Rourke's advice and "stick close to big timber," and, further, in cases where there is much water in the soil, such timber should be used from close to the top to very near the bottom of the trench. A special study of the conditions is necessary in each case, and the speaker does not believe that any general formula for earth pressures is practicable. Mr. Gahagan.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

THE REINFORCED CONCRETE WORK OF THE McGRAW BUILDING.

Discussion.*

By Messrs. H. F. Tucker, W. J. Douglas, Carl Gayler, J. A. Jamieson, Walter M. Smith, and Clarence W. Noble.

Mr. Tucker. H. F. Tucker, Assoc. M. Am. Soc. C. E. (by letter).—Professor Burr and the contractors who erected the McGraw Building are certainly to be congratulated upon having designed and built a structure of reinforced concrete of such unusual height. The fact that the building did not collapse during construction, and is even getting stronger with age, ought to be encouragement enough for prospective builders who, perhaps, have become unduly prejudiced against building material of this class.

It seems important to the writer, however, that the fact should be brought out clearly—for prospective builders and for the Engineering Profession as well—that the structural features of the building were not designed by an architect or by a contracting firm. In no way is this statement intended to claim for the Engineering Profession any credit which is not due, or to place it above either of the others. It is simply intended to point out the success attendant upon harmonious co-operation between these three distinct professions: the architectural, the engineering, and the contracting.

The writer believes that it is only by each keeping strictly to his domain that the perfect can be most closely approximated. It is true that the architect must know considerable about engineering, in order that he may design a possibility, but he cannot be both architect and

* This discussion (of the paper by William H. Burr, M. Am. Soc. C. E., printed in *Proceedings* for October, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

engineer, nowadays, and excel in either. The engineer must know a great deal about construction, in order that he may design economically. A contracting firm should be purely a contracting firm, and not "contracting and engineering," though such a firm should employ competent engineers in its service, but not for the purpose of doing the work of the consulting engineer. Even in the cost-plus-a-fixed-sum system, where there should be no incentive to "skin," there is the temptation, if such a firm does the designing, to please the unsuspecting owner by providing a design based too evidently on cheapness rather than on proper strength. Mr. Tucker.

It is the writer's firm conviction that, had the McGraw Building not been designed by an independent, unbiased engineer, the success of such an undertaking would not have been assured.

Professor Burr has brought out in his paper many points in reinforced concrete design which are frequently overlooked. The most important point is the study of the design with a view to saving money by duplication and simplicity of form work. In steel construction it is usually found more economical to run one section of column up two or three stories before making a change. So, also, in reinforced concrete construction, especially in a design of this type, where much of the stress is taken by the steel, it will be found cheaper to vary the steel, and sometimes the mix, leaving the outside dimensions of the column unchanged for several stories.

Uniformity, as much as possible, everywhere, even in depth and width of beams and girders, will usually result in a big saving in labor. On the other hand, irregularities produce what might be called a very large coefficient of friction in the carpenter's mind, and his speed is reduced to a remarkable degree. Simplicity and duplication in the reinforcing will result usually in a large saving. The fewer bends in the steel, and the more pieces that can conveniently be made into a unit, the better. It has always seemed to the writer that the bending of floor rods is not economical practice. It is hard to hold the rods thus bent from tipping over, and especially with round rods, which are cheap; two layers of rods, one in the bottom of the slab and one in the top, both continuous, seem to be cheaper, especially for thin slabs and short spans.

It appears from the details on Plate XCIV* that every other slab rod is turned up over the beams, thus giving only half as much steel to resist the negative bending over the beams as at the middle of the span, where, if the author had been calculating on continuity, the moment is less than $\frac{W\,l}{10}$. If this is the correct interpretation of the drawings, it would seem that there is either a redundancy of steel at mid-span or an insufficiency over the beams.

* *Proceedings*, Am. Soc. C. E., for October, 1907.

Mr. Tucker. The writer is in doubt as to whether it is economical to cast brackets under the ends of the girders and beams connecting to columns, as a brace against wind stresses, even in a high building, if it is as broad as the one under discussion. A deeper beam, if there is head room to spare, would simplify the forms, and make them more easily adapted to longer spans where the column section changes. When one sees a steel-framed building of ten or eleven stories and only 20 or 30 ft. from front to back, braced against wind by the ordinary web connection supplemented by 3½ by 2½-in. angle-lugs at the top and bottom of 20 or 24-in. I-beams, as was actually seen in Washington, D. C., he begins to wonder why a 30-in. reinforced concrete girder could not be connected to its column, far more stiffly and safely, by a few diagonal rods, and without the use of expensive brackets.

The removal of column forms, even with the substantial steel reinforcement in the columns of the McGraw Building, should not be reduced to the "minimum of time." To be sure, the lower columns would not have nearly all their dead load, but a column is a delicate thing, and really the backbone of such a structure.

In regard to such work being conducted successfully, under proper conditions, through a severe winter: The writer was connected in a professional way with a number of large reinforced concrete factory buildings for a manufacturing concern in Canada, last winter. Work was being pushed, as the contract time was urging the contractors to complete the buildings. It may not have been a severe Canadian winter, but it was far ahead of any Boston winter of the last two decades at least. The floors of the factory and shipping buildings were designed to carry a live load of 250 lb. In the spring the architect tested the shipping building floor "which suffered the most by frost, and it sustained a load of sand and stone of 450 lb. per sq. ft. without any deflection." It is probable that, through arch action in the load, or adjoining slab and beam action, the test did not show the actual strength of the floor; but, even so, it demonstrates the possibility of combating a cold climate successfully.

Mr. Douglas. W. J. DOUGLAS, M. AM. SOC. C. E. (by letter).—In reading this paper the writer's attention was called, as it often is in considering reinforced concrete designs, to the apparent waste of steel when used as reinforcement for concrete-steel compression members. In this particular case, the writer refers to the columns, which are heavily reinforced.

According to the author, the lower columns contain 10% of reinforcement, which reinforcement carries 57% of the total load; while, at the ninth story, the reinforcement is reduced to 3½%, carrying at this point 30% of the total load.

On the basis of the assumptions stated, namely, 750 lb. compression for concrete and a ratio of moduli of 12, the steel in the

columns can only be stressed to 9 000 lb., plus some small erection stress. Mr. Douglas.

Now, considering the lower columns with their 10% reinforcement, assuming the cross-section of the concrete to be 625 sq. in., less about 56 sq. in. for the steel, it is found that the concrete in the columns is carrying a total load of approximately $569 \times 750 = 426\,750$ lb., and the steel, having a cross-section of 56 in., carries a total stress of 504 000 lb., making the total load on these columns 930 750 lb.

If, for this concrete-steel column, an ordinary steel column should be substituted, it would only require 58.2 sq. in. of steel. If it were possible, in the concrete-steel columns, to stress the steel up to 16 000 lb., only 31.5 sq. in. of reinforcement would be required, instead of 56.2 sq. in., therefore, there is a waste of 24.7 sq. in. of steel, or 83.9 lb. per lin. ft., which steel would cost about $3.36 per lin. ft.

In the ninth story, this amount, on the basis of the foregoing, would be reduced to about 60 cents. Assuming an average of $1.95 per ft. for steel wasted on account of its low compressive stress, there would be a total loss in the entire structure of about $13 600. (The writer, of course, acknowledges that this additional steel is an additional factor of safety, but the point that he is trying to bring out is, that it appears to be an uneconomical way of providing for a factor of safety.)

It is not the writer's intention to criticise the building in question, because he realizes that the circumstances were such that it was quite impossible to have saved this steel, yet he believes that in many buildings—and he is certain that in many bridges—it is possible to stress the steel in compression, both in columns and in girders, to about 16 000 lb. by designing the structure so as to make the steel in compression carry all or nearly all the compressive stress due to dead load, and he believes that this may be attained economically.

A case of a concrete-steel bridge (girder), now under construction in the District of Columbia, may be cited: On account of the limiting conditions, it was necessary to reinforce the compression chords of this bridge with a large percentage of steel. As the writer only stresses concrete in work of this class to 450 lb., he could not calculate that the steel in compression, under a design of the customary type, would carry more than 6 750 lb. per sq. in. The reinforcement consisted of two riveted trusses having a depth of about 6½ ft. The floor system also consisted of reinforced concrete, the beams of which were reinforced with built-up, steel I-beam sections, the full end shear in the beams being developed in the steel connections of the floor beams and main girders.

This type of reinforcement was selected by the writer for the following reasons: its ease of erection; the comparative certainty with which the stresses could be calculated; the certainty of having the steel located in the actual construction in accordance with the theoretical

Mr. Douglas. relation to the concrete; positive anchorages could be obtained for all members, particularly as to the connection of the web members and the chords; the girders have a small factor of safety in themselves; the forming work was simplified; the cost of depositing concrete was possibly decreased; and, because there was a great saving in the cross-section of the steel compression members on account of the practicability of stressing the steel in compression to approximately 16 000 lb.

The forms for the entire structure are to be suspended from the girder and from the floor beams. The design contemplates the jacketing of the floor system first, then the jacketing of the large girder, by which methods of procedure the steel girder will be made to carry almost the entire dead load, exclusive of the paving. The live-load stresses in the steel and the concrete will, of course, be distributed on the basis of the ratio of moduli.

In regard to the construction of large girders for bridges, which are exposed to the elements, it is thought that this method is a particularly good one because the amount of flexure in the concrete-steel girder is cut down to a minimum, therefore the possibility of the formation of incipient cracks on the tension flange of the concrete girder is also cut down to a minimum. Whether or not the formation of these tension cracks on exposed girders is a matter of import is, of course, a matter of conjecture rather than fact. It is believed that this principle may be applied to many buildings without unnecessary delay, and without an additional cost of forming.

In a second bridge, the writer is going to concrete the columns last, after the entire superstructure above the columns has been completed. In this way, the steel reinforcement, which consists of an ordinary steel column, will be made to carry the entire dead load.

Professor Burr, referring to the concrete in the columns, says: "As it is completely embraced or surrounded by the steel angles and lacing bars, it is steel 'banded' in the most effective manner possible."

The writer is rather inclined to believe that if the steel bands are not attached rigidly to the vertical reinforcement, a stronger column will be attained. His reason for this is that the concrete, in setting up, shrinks, particularly where the day's pour results in a long length of column, and soupy concrete is used, which is almost universal practice.

Now, as it is thought that this shrinkage takes place after initial set, it seems manifest to the writer that detached bands would give better results. As a matter of fact, it seems probable that the concrete adjacent to the vertical reinforcement will be injured more or less, on account of this vertical shrinkage, but this cannot be helped, and must occur even when plain round rods are used, unless they are mathematically straight. Therefore, it appears to the writer that,

with the same cross-section of steel and concrete, the ordinary star column, with detachable steel bands, would be stronger. Mr. Douglas.

CARL GAYLER, M. AM. SOC. C. E. (by letter).—The McGraw Building differs from the numerous purely reinforced concrete buildings which have been constructed all over the country principally in the type of the columns used. As described in the paper, these columns are built of steel angles, laced on all four sides and filled with concrete, and have been proportioned on the assumption, not only that both materials carry the loads jointly, but, furthermore, that through the lateral support afforded by the steelwork, the strength of the concrete is increased to such an extent that a unit pressure of 750 lb. per sq. in. —more than twice the pressure per square inch allowed by the Building Department of the City of New York on reinforced concrete columns—was deemed permissible. The unit pressure on the steel was then determined according to the ratio of the moduli of elasticity of the two materials (1:12). Such unit stresses in the columns permitted a height of eleven stories for the McGraw Building, with reasonable sizes for the columns, even in the lower stories and basement. Mr. Gayler.

Now, it is clear that if these assumptions were correct, that is, if the two materials of which the columns are composed were to act as a unit, with the additional advantage of greatly increased carrying capacity of the concrete, the superiority of such columns over the reinforced concrete column, in regard to reduced areas of cross-section, and safety, and over the steel column in regard to economy, would be so great that buildings constructed on the same plan, and of great height, would soon be generally built and become strong competitors of the steel skyscraper. But, are the claims for these combination columns justified? Not once in this paper is there mentioned the fact that concrete, in drying in air, shrinks. Waiving the question of relative changes in the dimensions of the concrete and of the steel under changes of temperature, or of the relative compressibility of the two materials under loading, the thoroughly established fact of the contraction of concrete in the process of hardening and drying remains. The phenomenal increase in the use of concrete for engineering works during the last ten years could not have taken place unless full account had been taken of this important quality of concrete. The exact amount of this shrinkage is unknown, but that the changes in the volume of concrete are considerable, probably greater than those under subsequent changes of temperature, is just as sure as that no corresponding reduction in the size and length of the steel column, put up in the building ready to receive the wet concrete, will take place. No amount of care taken in pouring and stirring will alter this inherent characteristic of all concrete used above ground.

Thus, in the McGraw Building, there are composite columns, about

Mr. Gayler. 150 ft. long, of varying cross-section, consisting of an outer shell of steel and filled with a material which, as any engineer who has had any experience with concrete knows, will at certain unknown distances develop shrinkage cracks. That the surface contact between the steel and the embedded concrete will have an influence on the manner of shrinkage, and therefore on the frequency and position of these cracks, is true, but to suppose that the latter are obviated through this contact is equivalent to assuming that the steel plates, angles, and rivet heads will, through their mere contact, stretch the enclosed concrete, uniformly, throughout the aggregate height of the eleven stories of the building. This would be a bold position to maintain, the more so because the contact between the steel and the concrete is not at all uniform: Throughout the greater part of the length of the columns the concrete is confined by angles and lace bars, with the rivet heads spaced some distance apart, while at the joints of the steel columns and, to some extent, at the points of lateral connections, it is solidly enclosed by angles and plates with closely spaced rivet heads.

To consider the influence of the inner surface of the rigid steel columns of the McGraw Building on the enclosed concrete, as far as shrinkage of the latter material is concerned, equal to, or even greater than, the effect of shrinkage rods of the ordinary reinforced concrete work, is a fallacy, because the shrinkage rod, owing to its light cross-section, partakes to some extent of the deformations of the concrete and, owing to its position inside of the mass of the concrete, is able to take up the stresses induced by the changes in form of the concrete, neither of which conditions is fulfilled by the steel shell. By deformations of the concrete is here meant not only the reduction of length, but also reduction of cross-section in the process of drying. The writer considers it anything but an extravagant statement to say that, in places, the concrete after hardening will not cling to all the four inner sides of the steel column.

To assume that the concrete contracts in such a manner that it forms a monolithic column, as high as the building, and bearing on the foundations in the basement, in other words, that the mode of vertical contraction of the concrete takes place as if there were no contact with the steel at all is, of course, out of the question and could not be maintained by the designers of this building for one moment, as in the paper great stress is laid on the "firm and complete hold or bond between the steelwork of each column and the concrete enclosed within it." The lace bars have been specially arranged so as to counteract such independent movement of the concrete as much as possible.

The above stated considerations have led the writer to the following conclusions:

1.—The McGraw Building is a reinforced concrete structure with composite columns, the carrying capacity of which columns consists in the steel.

2.—The concrete filling of the columns is an excellent provision for the prevention of rust, highly advantageous, together with the concrete casing of the columns, in case of fire, besides affording some additional rigidity to the latticed portion of the columns. Mr. Gayler.

3.—The wise provision, insisted on by the Bureau of Buildings of the City of New York, "that the cross-section of the steel in any column at any floor shall be sufficient to carry the entire dead load above that section without stressing the steel to more than 16 000 lb. per sq. in.," is, in view of the great weight of the building, a guaranty for the reasonable safety of the McGraw Building.

J. A. JAMIESON, M. AM. SOC. C. E. (by letter).—Referring to the columns built of four steel angles, latticed diagonally, and the interior filled with concrete: The writer cannot agree with the author's claim that "the concrete is 'banded' in the most effective manner possible." In fact, he believes it to be obvious that the steel members of this column, as built, cannot possibly retard the lateral swelling of the concrete due to the compressive load upon it. Mr. Jamieson.

Assuming 12 to be approximately correct for the ratio between the moduli of elasticity for steel and concrete, and also assuming that each of the materials will take its computed share of the load, there will be an equal shortening of both the concrete and steel angles.

Now, it is well known that the transverse expansion of concrete under compression is very much less than the longitudinal shortening. Under a working stress of 750 lb. per sq. in., the former is probably not greater than 20% of the latter. With the lattice bars set at an angle of 30° from the horizontal, as the steel angles shorten under compression, these lattice bars, with their rivets acting as pivots, will force the angles apart, and the transverse expansion of the steel members will be much greater than the concrete, under which condition it must be obvious that the steel cannot band or restrain the concrete and thereby increase its power of resistance. In addition to this, it would be expected that the bond or adhesion between the steel and concrete would be destroyed.

If the steel angles had been connected by horizontal bars or battens, a much more efficient column would have been obtained; it would still, however, be far from 'banded" in the most effective manner possible, since the thin straight bars, spaced at considerable distances apart, would not present material resistance to the lateral swelling of the concrete.

The column shown by the author cannot properly be called a reinforced-concrete column, but should be termed a composite concrete and steel column, having a strength in direct compression equal to the sum of the resistance offered by the steel and the concrete, using 12 as the ratio between the moduli of elasticity of the concrete and the steel, as required by the New York Building Code. Since, however,

Mr. Jamieson. the concrete was placed in the work in a semi-liquid state, there would be considerable shrinkage during the setting and hardening period, which would most probably produce corresponding initial compressive stress in the steel and tensile stress in the concrete, and this would materially increase the load on the steel and reduce the load on the concrete and most probably cause the load ratio to become nearer 16 than 12.

The writer fully believes that reinforced concrete, as a structural material, is particularly well adapted for such buildings as the one under discussion, and does not contend that the column, as built, and under working stresses of 750 lb. for 1 : 2 : 4 unreinforced concrete, and 9 000 lb. per sq. in. for steel, is an unsafe one; in fact, he believes it to have an ample factor of safety, but he contends that the assumptions on which it is based are theoretically untenable, and are entirely at variance with all reliable information thus far obtained from tests.

The compressive member, or column, is probably the most difficult problem with which one has to deal, in the majority of structures, and it may not be out of place to venture the opinion that, up to the present time, the only rational reinforced-concrete column produced, in which the stresses are capable of being analyzed and closely calculated, and the one which gives the highest efficiency for the materials used, is that type in which the concrete is used in direct compression and the steel in tension only, designed to resist the lateral expansion of the concrete, thereby greatly increasing its power of resistance under compressive loads.

The tests conducted by M. Considére very fully proved the efficiency of this type of column, when properly designed and built. Subsequent tests conducted by A. N. Talbot, M. Am. Soc. C. E., have broadly confirmed the results obtained by M. Considére. Professor Talbot's tests, however, appear to indicate that the hooping remains inactive until a considerable load has been applied to the column, but it is believed that this is entirely due to the lateral shrinkage of the concrete, owing to insufficient water being attained, during the hardening period, to insure full crystallization.

It is true that many irrational designs of columns of this type have been produced and used; notably, those having a considerable percentage of longitudinal rods, with hoops or bands spaced at too great distances apart to prevent the lateral swelling of the concrete, with the consequent deflection of the rods and very high stresses in the bands, or those having spirals wound at too great a pitch, which increase in diameter with the shortening of the column, and also leave the concrete free to swell between the hoops. The hooped column, however, is gradually becoming better understood, and is being studied by many able engineers, and one may look forward to material improvement in the future.

WALTER M. SMITH, M. AM. SOC. C. E.—About three years ago, the speaker had occasion to observe the condition of stress of reinforcing steel bars in concrete. In constructing a battery of high-power guns at Charleston, S. C., the ceilings of the rooms had "Johnson" corrugated bars placed in the concrete, about 4 in. above the surface. The thickness of concrete from the ceiling to the top was about 10 ft., but at a height of about 2 ft. above the ceiling a water-proofing layer of asphalt was placed separating the concrete above from that below. The span, in the direction of the reinforcing bars, was about 11 ft. Bars were placed of a sufficient size, and at a proper distance to take all the tension, with the 2-ft. thickness of concrete acting as a set of beams 11 ft. in length. The bars were computed to be stressed in tension at 16 000 lb. per sq. in. Mr. Smith.

A few months after this concrete had been finished, it became necessary to cut a recess in the ceiling to a depth of about 1 or 2 in. beyond the reinforcing bars and about 2 ft. long in the direction of their length. When the concrete was cut from around the bars they sprang out of line, showing that they were in compression instead of in tension. In the speaker's opinion, the only way to explain this is that the concrete in setting had shrunk sufficiently to put a considerable compressive stress in the steel. The concrete in the lower part of the beam, therefore, was taking all the tension, and the steel could take none until the tension in the concrete became sufficient to cause it to stretch to the position it occupied when constructed. When this point is reached the steel begins to take the tension, and at a constantly increasing ratio as the concrete begins to develop fine hair-like cracks extending gradually upward from the bottom. The depth of concrete was very great in proportion to the span, in this case, therefore the proportion of steel was very small. The concrete on the tension side of the beam was not stressed very high in carrying the load, without considering the steel.

This is the only instance in the speaker's knowledge where concrete has been cut from around reinforcing bars and thereby a chance given to observe the condition of stress in the bars. He is glad, therefore, of this opportunity to bring it to the attention of engineers.

In view of the foregoing facts, it seems to the speaker that it is somewhat risky to construct long columns, as in the McGraw Building, with a large percentage of steel, and expect the concrete to take any portion of the load to the foundation. In the speaker's opinion, the concrete, being prevented from contracting longitudinally by the steel, will be in tension although it may show no appreciable cracks, and cannot, therefore, be relied on to take its due proportion of the load to the foundation. In the hooped column, if only enough longitudinal reinforcement be placed to hold the hoops in position during construction, the concrete is free to contract in setting and, therefore, is not in the same condition of stress.

Mr. Smith. The speaker believes that the fact mentioned by Mr. Goodrich, of the shrinkage of the concrete in the center of columns, reinforced as these are, goes to prove that the steel reinforcement does prevent the shrinkage of the concrete during setting and leaves it in a condition of tension.

Mr. Noble. CLARENCE W. NOBLE, ASSOC. M. AM. SOC. C. E. (by letter).—The writer has always been of the opinion that insufficient consideration has been given to the question of the proper division of the total bending moment into the positive moment, provided for in the center of the span, and the negative moment, provided for over the points of support. Every question, connected with the moment of resistance of a concrete beam, has been discussed until there is practicable agreement as to the actual conditions prevailing, and the only discrepancies of any moment are those arising from the fact that certain engineers, in their desire for simplicity, knowingly, prefer to ignore various phases of the matter. A far larger percentage of variation in the practice of different engineers is accounted for by the variation in the division between the positive and negative bending moments than in any other single consideration. In fact, this matter has come to the point where practice is now being crystallized by the adoption of building laws in various cities almost without any general engineering discussion of the question.

Obviously, with a uniform load distributed over several adjoining spans, there are a number of ways in which the total bending moment may be met. The system as a whole may be regarded as a series of simple beams, reinforced entirely on the bottom. It may also be regarded as a series of balanced cantilevers, extending out on each side from each point of support, and meeting at the center of the span, the reinforcement in this case being entirely at the top of the beam. By varying the quantity of steel at the bottom and top of the beam, it may be divided so as to be a combination of these two systems, with points of contraflexure located arbitrarily at the option of the engineer.

That this last statement is true, may be seen readily by a moment's consideration. The point of contraflexure in the first case—that of a series of simple beams—is directly over the point of support for each of the two adjoining spans. There is, in this case, no curve convex upward, and a cusp occurs at the point of support. This, of course, means that when fully loaded, a crack may be expected there. In the second case—that of a series of cantilevers—exactly the reverse takes place. There is no curve concave upward. The points of the contraflexure are concentrated at the center of the span, forming a cusp; and, under fully-loaded conditions, a crack will occur at the bottom of the beam at this point.

Now, by removing a portion of the negative reinforcement over the points of supports, these two superimposed points of contraflexure

will be drawn apart and will approach the columns, and positive reinforcement will be required in the center of the span, in order to give the beam action over the interval between these points. Just how much positive reinforcement is needed will depend on the remaining amount of negative reinforcement. Mr. Noble.

As is well known, wherever the system of continuous beams extends indefinitely in either direction, the negative bending moment is represented by the formula, $\frac{W\,l}{12}$, and the positive bending moment by $\frac{W\,l}{24}$. This condition, however, only takes place when both the negative and positive bending moments are adequately met by moments of resistance, and then only when the unit stresses in the material furnishing this amount of resistance are the same at the center span and the points of support. As conditions vary from this, say by decreasing the moment of resistance over the point of support, thus bringing the point of contraflexure toward the ends of the clear spans, the curvature over the point of support is increased and consequently the unit stresses at this point are increased.

Only one condition is theoretically imposed for the division of bending moment between positive and negative points. This, as the total moment, must equal $\frac{W\,l}{8}$. The complement of $\frac{W\,l}{10}$, of the center span, as demanded by the Building Laws of New York City, is $\frac{W\,l}{40}$ at the point of support. This condition is actually required in French practice, although it seems to be largely ignored in the United States. If $\frac{W\,l}{12}$ is used at the center of the span, theoretically, then $\frac{W\,l}{24}$ must be used at the point of support; and if $\frac{W\,l}{16}$ is provided for at the center of the span, theoretically, $\frac{W\,l}{16}$ must also be provided for over the point of support.

Actually, one cannot "sail so close to the wind." If the French practice is followed and $\frac{W\,l}{10}$ is provided at the center of the span and $\frac{W\,l}{40}$ over the points of support, and if at any time actually theoretical conditions are realized, the reinforcement over the point of support will be stretched far beyond its elastic limit. Consequently, the actual bending moment at the center of the span will become $\frac{W\,l}{8}$. It is possible that this statement should be "taken with a grain of salt," owing to the fact that the beam may be incorporated into the general floor

Mr. Noble. system in such a way that, should an actual condition represented by $\frac{W l}{8}$ occur, the extreme bottom fibers of the beam would be confined so much at the ends that they would not have opportunity to elongate, and therefore an internal arching effect would be set up. If $\frac{W l}{12}$ be adopted at the center of the beam and $\frac{W l}{24}$ at the point of support, obviously the unit stresses over the point of support will be much greater than at the center of the span, thus bringing them probably very close to the elastic limit. If the actual theoretical condition is adopted, that is, $\frac{W l}{24}$ at the center of the span, and $\frac{W l}{12}$ at the point of support, the use of T-beams is prevented, as the section will not reverse, and it would be necessary to increase largely the depth of the beam at the columns and for some distance on each side. For this practical reason, the writer knows of no work in which this set of coefficients has been used.

There is another consideration, also, which prevents too close an adherence to any theoretical division of the total bending moment of $\frac{W l}{8}$. This is due to the fact that there are conditions of partial loading in which greater bending moments can be brought about in various points of the system than under strictly uniform load. If, for example, the beam extends over several panels, and the load is only imposed on alternate panels, intervening ones being occupied by aisles, it is questionable whether there would be any positive moment in the aisles, and it is certain that the bending moment in the centers of the spans taking the load would be considerably greater than $\frac{W l}{24}$. If provision is made for $\frac{W l}{12}$ at this point, therefore, and for $\frac{W l}{12}$ also, at the point of support, a system is adopted which will never meet the theoretical conditions occurring at the same time in actual practice, but which will meet any possible stresses occurring at any point in the system due to the variation of this theoretical condition. The resulting beam also has the advantage of being uniform in section.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

CHARLES EZRA HEQUEMBOURG,* M. Am. Soc. C. E.

DIED OCTOBER 17TH, 1907.

Charles Ezra Hequembourg was the eldest son of the Reverend Charles Louis Hequembourg (Yale, 1836), a distinguished Presbyterian clergyman and author, whose grandfather, Charles Louis Hequembourg, came to America from Rouen, France, in 1778. His mother was Emelia Williams Hequembourg, a direct descendant of Stephen Williams. Under the wise guidance of his parents, he began at once to cultivate the qualities he had inherited, and these carried him through a remarkably successful career.

He was born on July 9th, 1845, in what was then the Village of Dunkirk, Chautauqua County, New York, which place he always made his home, though for forty years his business interests were mostly in other fields. His education was received in the public schools of Dunkirk and Dansville, New York, and Warren, Pennsylvania, in which places his father successively established his home and reared a family of seven children. Forced by circumstances, it was necessary for him to begin the battle of life while very young, and he earned his first wages working in the summer on the farm, and during the winter season making boats and skiffs to be used in the spring by the lumbermen of that vicinity. As he grew older, his interest in work of this nature quickened until he finally took to the trade of carpenter. At the age of 18, however, he laid aside his tools, and, with Company D, 68th Regiment, N. G. N. Y., went to the front and later joined the Army of the Cumberland.

When he received his discharge, at the end of the war, he began to acquire his engineering knowledge, and practiced in Tennessee and Kentucky, where he soon had charge of the field work, surveys, mapping lands, drilling wells, building pipe lines, etc., for the Tennessee and Cumberland Oil and Mining Company.

In 1870 Mr. Hequembourg returned to Dunkirk, and entered the contracting business. His first large contract was the erection of what is now School Building No. 2, in that city. The next year he erected the first brick schoolhouse in Titusville, Pennsylvania. During 1871 and 1872, while filling the office of Village Engineer, he constructed the Dunkirk Water-Works, a direct-pressure system, costing

* Memoir prepared by Thomas W. Symons, M. Am. Soc. C. E.

about $100 000. In 1873 and 1874, as engineer and contractor, he constructed the water-works systems of the Towns of Hyde Park and Lake, now part of the City of Chicago. These were also direct-pressure systems, and cost about $1 250 000. Later, at Bradford, Pennsylvania, he erected the St. James Hotel building, the second brick edifice that city possessed, and now its principal hotel. As a direct result of his location, he naturally became interested in oil developments, and was one of the early operators in the Pennsylvania field. He took special interest, however, in natural gas, of which he made an exhaustive study, and to the end of his life was an authority on all matters pertaining to the production and use of gas.

In 1878, as President and Engineer, with associates, Mr. Hequembourg organized the Bradford Gas, Light and Heating Company, and the Tarport and Kendal Gas Light and Heating Company. These were the first corporations to supply natural gas for light and fuel to a municipality. The original supply was obtained from natural pressure, but in 1880 this was superseded by a pumping station at Rixford, Pennsylvania, with a capacity of 6 000 000 cu. ft. per day. It was from the experience and knowledge thus acquired in the Pennsylvania fields that, in 1888, as President and Engineer of the Columbus Construction Company, he was able to undertake the task of connecting Chicago with the gas fields of Indiana, and in this undertaking he was most successful. In 1892, the Columbus Construction Company completed and turned over, to the owners of the Indiana Natural Gas and Oil Company, and the Chicago Economic Fuel Gas Company, what was then the largest and longest gas pipe-line system in the world. Fully equipped with modern pumping stations and appliances, this pipe-line is now in successful and profitable operation.

Mr. Hequembourg was strictly a self-made man. His parents, with a large family to rear, and with a limited income, were unable to give him the advantages he lived to give his sons and daughters, and from an early age he began to face the stern problems of life. He looked about him, saw his opportunities, and grasped them, and the secret of his success was that he always investigated thoroughly any matter which was of interest to him at the time. His mind was extraordinary, and drifted naturally into scientific channels, although he often remarked that his greatest ambition was to be a lawyer, and, in representing his associates or in his own work, he took actual delight in probing into the depths of the legal questions which were presented. He possessed a complete law and reference library, in addition to his collection of scientific works, and his friends often accused him of never being content unless he had a lawsuit on his hands.

After retiring from active practice, in 1892, he took up his home life at Dunkirk, and to gratify his longing for scientific research and knowledge, he erected near his residence an observatory consisting of

a tower 65 ft. high, in the top gallery of which, mounted on a brick pedestal, was placed a 25-ft. telescope, with a 9-in. objective. This observatory is fitted with all modern appliances, instruments of precision, etc. On the other floors of the tower are arranged the library, photographic room, and laboratory. It was here that Mr. Hequembourg loved to entertain his friends and enjoy his astronomical work until, unfortunately, in 1901, he slipped on an icy pavement and fractured his leg. After that he was not able to climb the tower stairs without considerable annoyance, and he was forced to give up his work in this field. Not content to remain idle, however, he became interested in automobile construction, and, a few years ago, took out a patent on an improved non-puncturable tire, but not until he had made many long and serious tests of his idea.

Mr. Hequembourg was a devoted and loving husband, and a kind and indulgent father, and was very happy in his home life, constantly striving to make his family comfortable and happy.

In March, 1904, he was selected by the people of Dunkirk as their Mayor. His election was not of a political nature, but was due rather to a movement for reform, and his administration was marked by an increase in local patriotism.

The following term he was on the ticket of both parties, and carried the city through another season of prosperity. His attention to municipal affairs was marked by the energy and earnestness with which he conducted his office. One of his fondest hopes was to live to see Dunkirk become a large city, and he believed that, on account of its natural advantages, it could be made so by proper co-operation. Dunkirk Harbor was the subject of special interest to him. At one time, at his own expense, he made surveys and soundings of this harbor, and brought about a public movement to get Congress to appropriate sufficient funds for the proper deepening of the channel and anchorage, and its protection by suitable breakwaters. This was accomplished, to a great extent, but Dunkirk needs another man, such as she has lost in Mr. Hequembourg, to come to the front and direct the gathering of the fruits of his labors in this field.

Mr. Hequembourg had been in excellent health all his life until last March, shortly after the death of a beloved son, Louis Max Hequembourg, a boy of 22 years, and a Junior in the College of Civil Engineering at Cornell University. The loss of this happy boy, whose future seemed so bright, and of whom he was so proud and hopeful, completely broke his heart, and from that day in March, when his boy was taken from him, he appeared to decline, and seven months afterward followed him to Fredonia, where he lies near him in the family plot in beautiful Forest Hill.

At St. Louis, in 1872, Mr. Hequembourg was married to Harriet E. Thurber, who survives him, with their son, Charles Guy Hequem-

bourg, an engineer in New York City, and their four daughters, Mrs. J. L. Hurlbert, of Dunkirk, Mrs. F. K. Wing, of Buffalo, and the Misses Jessie and Hilda Hequembourg, who live at home.

Charles Hequembourg was a man of great activities. Always thoughtful, conservative, and unassuming, he possessed great determination, and once having mapped out a course of action, no obstacle seemed so great as to be unsurmountable. He planned and solved large business problems with the skill of a master, in the fulfillment of which he crossed swords with many of the great captains of industry, and in the action was seldom, if ever, worsted. He commanded the respect of his associates, and all men with whom he came in contact, no matter on which side they stood. A large man, physically, he possessed a heart large in proportion, and was always sympathetic, kind, and courteous to all. He was surely one of God's noblemen. He possessed, in a marked degree, the qualities of self-reliance, courage and inflexibility of purpose. If these characteristics are applied to the branches of activity wherein his energy found an outlet, it is easy to understand why he was a successful engineer, and an instrument in the development of large interests, and why he has left behind him so many who will mourn his loss.

Mr. Hequembourg was a Thirty-third-degree Mason of the Ancient Order of the Accepted Scottish Rite. He was elected a Member of the American Society of Civil Engineers on June 5th, 1901, and, although he took no active part in Society matters, he was a close observer of all that transpired, and took the greatest pride in his membership.

PAUL ERNEST OBERNDORF, Jun. Am. Soc. C. E.*

Died October 13th, 1907.

Paul Ernest Oberndorf was born at Centralia, Kansas, on February 16th, 1885, and died of typhoid fever at the same place after a short illness, on October 13th, 1907.

His childhood and early youth were spent on the farm. In the autumn of 1900, he entered the Friends Preparatory School at Washington, D. C., and was graduated with honors in 1902. He entered Princeton University in September, 1902, and was graduated four years later with the degree of Civil Engineer. His record in college was of such character that, upon his graduation, he was offered an assistant professorship, but he chose rather to enter at once into the practical work and experience of his profession.

* Memoir prepared by L. R. Ash, M. Am. Soc. C. E.

He was first employed by Messrs. Waddell and Hedrick, of Kansas City, Missouri, as an assistant engineer upon the large viaduct, then building, between Kansas City, Missouri, and Kansas City, Kansas. After a short time he was sent as an assistant engineer on the substructure for a bridge over the Atchafalaya River, in Louisiana. This position required a man of judgment and precision, and Mr. Oberndorf did his work in such a manner as to mark him as a man of rare tact and ability for one so young. For the few months before his death, he was employed as draftsman in the office of Ira G. Hedrick, M. Am. Soc. C. E., and here, as in the field, his work showed him to be original and resourceful. Judging from the results of the little more than a year's work between his graduation and his death, Mr. Oberndorf undoubtedly had the qualities of a great engineer.

Mr. Oberndorf's temperament was a most happy one, his manner was cordial and friendly, and showed regard for the opinions and feelings of others. It is rare that one finds a more symmetrically developed, well rounded out man, in the highest sense of the term. His death was a great personal loss to his host of friends, for all who knew him loved him and were drawn to him by his gentleness, his manliness, and his magnetic personality.

Mr. Oberndorf was elected a Junior of the American Society of Civil Engineers on February 5th, 1907.